IMPACT OF SELECTED REGULATORY POLICIES ON THE U.S. FRUIT AND VEGETABLE INDUSTRY

By

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A DISSERTATION PRESENTED TO THE GRADUATE SCHOOL
OF THE UNIVERSITY OF FLORIDA IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE DEGREE OF
DOCTOR OF PHILOSOPHY

UNIVERSITY OF FLORIDA

2004

This work is dedicated to my parents and my wife.

ACKNOWLEDGMENTS

I have been very fortunate to work with my supervisory committee, whose guidance and encouragement were essential to the completion of my research. I would like to express my deep gratitude and appreciation to the chair of my supervisory committee, Dr. John VanSickle, for his exceptional advice, patience, and for the financial support through my graduate study in the Food and Resource Economics Department. I benefited from many discussions, insightful comments, and ideas from Dr. Edward Evans. His dedication allowed me to live up to my potential. I would also like to acknowledge my other committee members (Dr. Allen Wysocki, Dr. Richard Weldon, and Dr. Chunrong Ai) and Dr. Mark Brown for their concrete ideas and support. Finally, I would like to thank my wife and my parents for their enduring love and support.

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August 2004

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Major Department: Food and Resource Economics

The United States is one of the world's leading producers and consumers of fruit and vegetables. Fruit and vegetable production occurs throughout the United States, with the largest fresh fruit and vegetable acreage in California, Florida, and Texas. Our study used the spatial equilibrium model to determine the expected economic impacts of the North America Free Trade Agreement (NAFTA) and the phaseout of methyl bromide in the U.S. fruit and vegetable industry.

The first analysis relates to implementation of NAFTA. International trade is an important component of the U.S. fresh fruit and vegetable industry. Under NAFTA, all agricultural tariffs on trade between the United States, Mexico, and Canada will be eliminated. As a result, Mexican growers are expected to increase shipments to the United States as tariffs are eliminated for exports to the United States.

The second analysis relates to a ban on methyl bromide. Methyl bromide has been a critical soil fumigant used in the production of many agricultural commodities for many

years. The U.S. Clean Air Act of 1992, as amended in 1998, requires that methyl bromide be phased out of use by 2005. While significant progress has been made in developing alternatives to methyl bromide, no alternative has been identified that permits a seamless transition (where comparative advantage is minimally impacted by the elimination of methyl bromide, and the affected producers continue to compete with other producers).

To satisfy the utility-maximization condition, the elasticities used in the spatial equilibrium model are calculated from the popular functional forms of the inverse demand system. Demand analyses can be very sensitive to the chosen functional forms. Our study addresses this concern by proposing a formulation that obviates the need to choose among various functional forms of the inverse demand system.

Results of the spatial equilibrium analysis indicate that total production in the United States is expected to decrease after the implementation of NAFTA and the ban on methyl bromide. Mexico is expected to become a larger supplier of vegetables in the United States.

CHAPTER 1
INTRODUCTION

Overview of the Fruit and Vegetable Industry

The United States is one of the world's leading producers and consumers of fruits and vegetables. According to the U.S. Department of Agriculture, farmers earned $17.7 billion from the sale of fruits and vegetables in 2002. Annual per-capita use of fruits and vegetables rose 7% from 1990-1992 to 2000-2002, reaching 442 pounds as fresh consumption increased and processed consumption fell. Consumer expenditures for fruits and vegetables are growing faster than any food group (except meats).

The United States harvested 1.4 million tons of fruits and vegetables in 1999 (a 20% increase from 1990). Even though output has been rising, aggregate fruit and vegetable acreage has been relatively stable, indicating increasing production per acre. The major source of higher yields has been the introduction of more prolific hybrid varieties, many of which exhibit improved disease resistance and improved fruit set. Shifting from less-productive areas to higher-yielding areas has also contributed to higher U.S. yields over time. Fruit and vegetable output will likely continue to rise faster than population growth over the next decade because of increasing consumer demand and concerns about health and nutrition.

Fruit and vegetable production occurs throughout the United States, with the largest fresh fruit and vegetable acreage in California, Florida, Georgia, Arizona, and Texas. California and Florida produce the largest selection and quantity of fresh vegetables. Climate causes most domestic fruit and vegetable production to be seasonal, with the

largest harvests occurring during the summer and fall. Imports supplement domestic supplies, especially fresh products during the winter, resulting in increased choices for consumers. For example, Florida produces the majority of its domestic warm-season vegetables, such as fresh tomatoes, during the winter and spring, while California produces the bulk of its domestic output in the summer and fall. Fresh-tomato imports, primarily from Mexico, boost total supply during the first few months of the year, and compete directly with winter and early spring production from Florida. In value terms, Mexico supplies more than half (61%) of all the fruit and vegetable imports to the United States, with the majority being fresh-market vegetables. Canada is the second leading foreign supplier, with about 27% of the U.S. import market. Because of their obvious transportation advantages, Mexico and Canada have historically been the top two import suppliers to the United States. In value terms, fresh fruits and vegetables account for the largest share of fruit and vegetable imports, with about $2 billion in 1999. There is a definite seasonal pattern to U.S. fresh vegetable imports, with two-thirds of the import volume arriving between December and April (when U.S. production is low and is limited to the southern portions of the country). Most of these imports are tender warm-season vegetables such as tomatoes, peppers, squash, and cucumbers.

The United States is one of the world's leading producers of tomatoes, ranking second only to China. California and Florida make up almost two-thirds of the acreage used to grow fresh tomatoes in the United States. Fresh tomatoes lead in farm value ($920 million in 1999), along with lettuce and potatoes. U.S. fresh-tomato production steadily increased until 1992, when it peaked. Production then trended downward. Declines reflected sharply rising imports, weather extremes (excessive rains, wind, and

frost for several years), and increased competition from rapidly expanding greenhouse tomato growers. Per-acre yields for fresh tomatoes were off substantially in 1995 and 1996 from freezes, heavy rain, and low market prices. Severe flooding in Mexico sharply reduced its production and its exports to the United States. A smaller volume of imports and higher prices prompted Florida growers to harvest fields more intensively, resulting in record-high yields in Florida.

Although acreage has decreased over the past decade, Florida remains the leading domestic source of fresh tomatoes. Florida produced 42% of U.S. fresh tomatoes from 1997 through 1999. Florida's season (October to June) has the greatest production in April and May and again from November to January. The leading counties are Collier, Manatee, and Dade. Tomatoes, one of the highest-valued crops in Florida, bring in one-third of the state's vegetable cash receipts and 7% of all its agricultural cash receipts. As a result of decreased production in the northern states, Florida was able to increase its percentage of the U.S. domestic output from about 25% in 1960 to 42% in 1999. Because of higher prices during the winter, Florida accounts for 43% of the total value of the U.S. fresh-tomato crop.

California is the second-largest tomato-producing state, accounting for 31% of the fresh crop. Fresh tomatoes are produced across many counties in each season, except winter, with San Diego (spring and fall) and Fresno (summer) accounting for about one-third of the crop. Other important tomato-producing states in 1999 included Virginia, Georgia, Ohio, South Carolina, Tennessee, North Carolina, and New Jersey.

International trade is an important component of the U.S. fresh-tomato industry. The United States imported 32% of the fresh tomatoes it consumed in 1999 (up from

19% in 1994), and exported 7% of its annual crop. The percentage imported rose steadily after 1993 until low domestic prices discouraged imports in 1999. The United States, as a net importer of fresh tomatoes, had a tomato trade deficit in 1999 of $567 million. Mexico and Canada are important suppliers of fresh-tomatoes to the United States. Fresh-tomato imports mostly arrive from Mexico (about 83% in 1999).

Over the past two decades, the demand for bell peppers has been rising, reaching a record high in 2000. The United States is one of the world's biggest producers of bell peppers, ranking sixth behind China, Mexico, Turkey, Spain, and Nigeria. Because of strong demand, U.S. growers harvested 12% more bell pepper acreage in 2000 than in 1999. Bell peppers are produced and marketed year-round, with the domestic market peaking during May and June, and the import market peaking during the winter months. Although bell peppers are grown in 48 states, the U.S. industry is largely concentrated in California, Florida, and Texas. Trade plays an important role in the U.S. fresh bell-pepper market, with about 20% of fresh bell peppers coming from Canada and Mexico.

Originating in India, cucumbers were brought to the United States by Columbus, and have been grown here for several centuries. The United States produces 3% of the world's cucumbers, ranking fourth behind China, Turkey, and Iran. U.S. fresh-cucumber production reached a record high in 1999, but has trended lower since. Florida and Georgia are the leading states in the production of fresh-market cucumbers. Fresh-cucumber prices are the highest from January through April because of limited domestic supplies and higher production costs, and are the lowest in June when supplies are available from many areas. As a result, imports are strongest in January and February when U.S. production is limited by cool weather, and are the weakest in summer during

the height of the domestic season. Imports accounted for 45% of U.S. fresh-cucumber consumption from 2001through 2003, with most of the imports coming from Mexico and Canada.

Cultivated for thousands of years, watermelon is thought to have originated in Africa, and to have made its way to the United States with African slaves and European colonists. The United States ranks fourth in the world's watermelon production. Florida is the leading domestic source of fresh watermelon, followed by Texas, California, Georgia, and Arizona. Although value and production have been rising, the acreage devoted to watermelon has been trending lower over the past few decades. During the most recent decade, declining acreage has been due to a combination of rising per-acre yields and successive years of freeze damage in Florida and drought in Texas. Most watermelon is consumed fresh, even though there are several processed products in the market such as roasted seeds, pickled rind, and watermelon juice. Per-capita consumption of watermelon is highest in the West and lowest in the South.

In 1995 and 1996, fresh fruit and vegetable imports to the United States surged due to the combined effects of the devaluation of the Mexican peso, the rising demand for improved extended shelf-life varieties, and reduced domestic output due to adverse weather conditions. Florida and Mexico historically compete for the U.S. winter and early spring market. For example, Mexico dominates the market in the winter (when southern Florida is the predominant U.S. producer), and Florida dominates the market during the spring (when Mexican production seasonally declines). Another factor has been NAFTA. Under NAFTA, some of the tariffs on fresh-market tomatoes from Mexico were phased out over a 5-year period (1994-1998), while others had a 10-year

phaseout (1994-2003). For those tariffs phased out over the 10-year period, a tariff-rate-quota (TRQ), which increased at a 3% compound annual rate, was imposed. For example, cherry tomatoes have no TRQ because they were on the 5-year phaseout schedule. If tomato imports exceeded the quota, the over-quota volume was assessed tariffs at whichever was lower: the pre-NAFTA Most Favored Nation (MFN) tariff rate or the current MFN rate in effect. The tariff on fresh-market tomato imports from Canada fell to zero in 1998. However, a tariff snapback to the MFN rate can be triggered by certain price and acreage conditions until 2008.

The phaseout of methyl bromide also disadvantaged U.S. fruit and vegetable producers. Methyl bromide has been a critical soil fumigant in agricultural production for many years. While significant progress has been made in developing alternatives to methyl bromide, no alternative has been identified that permits a seamless transition (where comparative advantage is minimally impacted by eliminating of methyl bromide and the affected producers can continue to compete).

Study Overview

Our main objective of this study was to use the spatial equilibrium model to assess both the impacts of NAFTA and the phaseout of methyl bromide on the fruit and vegetable industry. To satisfy the utility-maximization condition, the elasticities used in the spatial equilibrium model were calculated from the inverse demand system. Consequently, the second objective was to examine the method of estimation and the method used to develop the model for the inverse demand system. The specified objectives are satisfied in two-essay format with the first essay concentrated on the estimation of the inverse demand system and the second essay concentrated on the spatial equilibrium analysis.

CHAPTER 2
DEMAND ANALYSIS ON FRUIT AND VEGETABLE INDUSTRY

Demand analyses can be very sensitive to chosen functional forms. Since no one specification best fits all data, researchers have been preoccupied with finding ways to select among various functional forms. Our study addresses this concern by proposing a formulation that obviates the need to choose among the various functional forms of the demand system. This approach was tested using four functional forms of the inverse demand system: the Rotterdam Inverse Demand System, the Laitinen and Theil's Inverse Demand System, the Almost Ideal Inverse Demand System, and the Rotterdam Almost Ideal Inverse Demand System.

Problematic Situation

Several studies in the past have considered the issue of how to choose among popular functional forms when conducting demand analyses. Parks (1969) used the average information inaccuracy concept. A relatively high average inaccuracy is taken to be an indicator of less-satisfactory behavior. Deaton (1978) applied a non-nested test to compare demand systems with the same dependent variables. However, this procedure is not suitable when comparing models with different dependent variables (as in the case of comparing the Almost Ideal Demand System with the Rotterdam Demand System).

Barten (1993) developed a method that can deal with non-nested models with different dependent variables. Briefly, the method starts with a hypothetical general model as a matrix-weighted linear combination of two or more basic models. A solution is found for one of the dependent variables, followed by estimating consistently the

transformed matrix weights associated with the other models. Next, statistical tests are carried out on the matrix weights to determine whether they are significantly different from zero. This matrix-weighted linear combination can be considered a synthetic demand-allocation system (which, under appropriate restrictions, yields different forms of the demand system). The synthetic model can therefore be used to statistically test which model best fits a particular data set. One drawback in applying this procedure is that it is necessary to impose a set of restrictions for the purpose of estimating. For example, the differentials need to be replaced by finite first differences, and the budget share needs to be replaced by its moving average. As a result, each functional form generates a different result.

Hypothesis

Our main hypothesis is that if the theoretical elasticities from the demand system in the theory are the same across all functional forms, then the empirical results of the elasticities from the demand system should also be the same across all functional forms.

Objectives

Our primary objective was to propose a formulation that obviates the need to choose among the popular functional forms when conducting a demand analysis and to empirically test this formulation using data on selected fruits and vegetables. The goal was to verify that the elasticities are the same across every functional form of the demand system. The secondary objective was to analyze the elasticities calculated from the coefficients of the inverse demand system.

Conceptual Framework

Inverse Demand Model

Barten and Bettendorf (1989) investigated the demand for fish by using the Rotterdam Inverse Demand System, which expresses relative or normalized prices as a function of total real expenditure and quantities of all goods. The Rotterdam Inverse Demand System is the inverse analog of the regular Rotterdam Demand System. From an empirical viewpoint, inverse and direct demand systems are not equivalent. To avoid statistical inconsistencies, the right-hand side variables in the systems should not be controlled by the decision maker. Therefore, it is better to use the inverse demand system for fresh fruits and vegetables.

It will be helpful to recall the consumer theory about ordinary direct demand functions derived from budget-constrained utility maximization. Types of consumer theory leading to systems of demand functions were summarized by Barten (1993), Deaton and Muellbauer (1980), and Theil (1965). Consumers pay p_iq_i for the desired amounts of commodity i, where p_i is the price of good i and q_i is the quantity of good i. These expenditures satisfy the budget equation, $\Sigma_i\, p_iq_i = m$, where m is the total budget of the consumer's allocation. The consumer's problem is to satisfy the budget constraint by selecting the quantities that maximize the utility function. This consumer problem can be stated as the utility maximization problem. It can be shown that under the appropriate form of the utility function, there exists a unique set of optimal quantities that maximize the utility function (subject to the budget constraint) for any set of given positive prices and income. These optimal quantities of income and prices are the Marshallian (Walrasian) demand functions,

$$q_i = f_i(m, p_1, \ldots, p_n), \tag{2-1}$$

with Walras' law: $\Sigma_i p_i q_i = m$. These demand functions follow the neoclassical restrictions, which include adding-up, homogeneity of degree zero in p and m, symmetry of the matrix of Slutsky substitution effects, and negative semi-definiteness of the matrix of Slutsky substitution effects. The implied restrictions are most conveniently expressed in terms of elasticities, which are derivatives of the logarithmic version of the direct demand functions,

$$d(ln\ q_i) = \eta_i\ d(ln\ m) + \Sigma_j\ \mu_{ij}\ d(ln\ p_j), \quad i, j = 1,\ldots, n, \tag{2-2}$$

where η_i is the income (budget, wealth, total expenditure) elasticity of demand for commodity i and is defined as

$$\eta_i = (\partial q_i / \partial m)(m / q_i) = \partial(ln\ q_i) / \partial(ln\ m), \tag{2-3}$$

μ_{ij} is the uncompensated price elasticity and is defined as

$$\mu_{ij} = (\partial q_i / \partial p_j)(p_j / q_i) = \partial(ln\ q_i) / \partial(ln\ p_j), \tag{2-4}$$

dx is the derivative of variable x, and $ln\ x$ is the natural logarithm of variable x.

The Slutsky, or compensated price, elasticity, ε_{ij}, can be represented in terms of the uncompensated price and income elasticities using the Slutsky equation,

$$\varepsilon_{ij} = \mu_{ij} + \eta_i w_j, \tag{2-5}$$

which involves the budget share,

$$w_i = p_i q_i / m. \tag{2-6}$$

This compensated price elasticity corresponds to the substitution effect of price changes, keeping utility constant. These elasticities inherit certain properties from the four neoclassical restrictions of q_i.

First, the adding-up conditions are

$$\Sigma_i\ w_i \eta_i = 1 \qquad \text{(Engel aggregation)}, \tag{2-7}$$

$$\Sigma_i\, w_i\mu_{ij} = -\, w_j \quad \text{(Cournot aggregation),} \tag{2-8}$$

$$\Sigma_i\, w_i\varepsilon_{ij} = 0 \qquad \text{(Slutsky aggregation).} \tag{2-9}$$

Second, the homogeneity of degree zero in p and m is

$$\Sigma_j\, \mu_{ij} = -\, \eta_i, \tag{2-10}$$

$$\Sigma_j\, \varepsilon_{ij} = 0. \tag{2-11}$$

Third, the symmetry of the matrix of Slutsky substitution effects is

$$w_i\varepsilon_{ij} = w_j\varepsilon_{ji}. \tag{2-12}$$

Fourth, the negativity condition is

$$\Sigma_i\, \Sigma_j\, x_i\, w_i\, \varepsilon_{ij}\, x_j < 0 \qquad x_i,\, x_j \neq \text{constant.} \tag{2-13}$$

From Walras' law, we can show that $d(ln\ m) = d(ln\ P) + d(ln\ Q)$:

$$\begin{aligned}
&m = \Sigma_i\, p_i q_i,\\
&dm = \Sigma_i\, q_i\, dp_i + \Sigma_i\, p_i\, dq_i,\\
&dm\, /\, m = \Sigma_i\, (q_i\, /\, m)\, dp_i + \Sigma_i\, (p_i\, /\, m)\, dq_i,\\
&d(ln\ m) = \Sigma_i\, (p_i q_i\, /\, m)(dp_i\, /\, p_i) + \Sigma_i\, (p_i q_i\, /\, m)(dq_i\, /\, q_i),\\
&d(ln\ m) = \Sigma_i\, w_i\, d(ln\ p_i) + \Sigma_i\, w_i\, d(ln\ q_i),\\
&d(ln\ m) = d(ln\ P) + d(ln\ Q),
\end{aligned} \tag{2-14}$$

where

$$d(ln\ P) = \Sigma_i\, w_i\, d(ln\ p_i) \qquad \text{(the Divisia price index),} \tag{2-15}$$

$$d(ln\ Q) = \Sigma_i\, w_i\, d(ln\ q_i) \qquad \text{(the Divisia volume index).} \tag{2-16}$$

An inverse demand system expresses the prices paid as a function of the total real expenditure and the quantities available of all goods. The coefficients of the quantities in the various inverse demand relations reflect interactions among the goods in their ability to satisfy wants. From an empirical viewpoint, inverse and regular demand systems are not equivalent. To avoid statistical inconsistencies, variables on the right-hand side in such systems of random-decision rules should be the ones that are not controlled by the

decision maker. In most industrialized economies, the consumer is both a price taker and a quantity adjuster for most of the products usually purchased. This is suitable with the regular demand system. On the other hand, for certain goods like fresh vegetables, supply is very inelastic in the short run, and the producers are virtually price takers. Price-taking producers and price-taking consumers are linked by traders who select a price they expect to clear in the market. The traders set the prices as a function of the quantities that are suitable in the inverse demand system.

To apply consumer-demand specifications to the model, the basic results of consumer-demand theory should be reviewed. From the utility-maximization problem for the consumer, we obtained a system of uncompensated inverse demand equations from the first-order conditions,

$$\pi_i = (\partial u / \partial q_i) / \Sigma_j (\partial u / \partial q_j) q_j, \qquad i = 1, 2, ..., n, \tag{2-17}$$

where $\pi_i = p_i / m$ is total expenditure or income $(m) = \Sigma_i p_i q_i$, u is utility, and p_i and q_i are price and quantity for good i, respectively. The budget share (w_i) can be found by using Equation 2-6 and $\partial x = x[\partial(ln\, x)]$,

$$w_i = [\partial(ln\, u) / \partial(ln\, q_i)] / \Sigma_j [\partial(ln\, u) / \partial(ln\, q_j)]. \tag{2-18}$$

First, we consider the Rotterdam Inverse Demand System (RIDS) by following Brown et al. (1995). A system of compensated inverse demand relationships can be found by working with the distance function, which is dual to the utility-maximization problem. The distance function indicates the minimum expenditure necessary to attain a specific utility level, u, at a given quality, q, which can be written as $g(u, q)$. By differentiating the distance function with respect to quantity, we get the compensated

inverse demands (which express price as a function of the quantities and specific utility level),

$$p_i = \partial g(u, q) / \partial q_i = p_i(u, q). \tag{2-19}$$

Consequently, we can also represent the compensated inverse demands for normalized prices, $\pi_i = p_i / m$, where $\Sigma_i p_i q_i = m$, by

$$\pi_i = p_i(u, q) / \Sigma_i [p_i(u, q).q] = \pi_i(u, q). \tag{2-20}$$

Next, we find the RIDS by totally differentiating this system of compensated inverse demand relationships. As π_i is a function of u and q_i, the total differentiate of π_i is

$$d\pi_i = (\partial \pi_i / \partial u)\, du + \Sigma_j (\partial \pi_i / \partial q_j)\, dq_j. \tag{2-21}$$

Consider a proportionate increase in q (i.e., $dq = kq^*$) where k is a positive scalar. We can then transform the term $(\partial \pi_i/\partial u)\, du$ to

$$\begin{aligned}
(\partial \pi_i / \partial u)\, du &= \pi_i[\partial(ln\ \pi_i) / \partial(ln\ u)]\ d(ln\ u), \\
(\partial \pi_i / \partial u)\, du &= \pi_i[\partial(ln\ \pi_i) / \partial(ln\ k)]\{d(ln\ u) / [\partial(ln\ u) / \partial(ln\ k)]\}, \\
(\partial \pi_i / \partial u)\, du &= \pi_i[\partial(ln\ \pi_i) / \partial(ln\ k)]\{[\Sigma_j (\partial(ln\ u) / \partial(ln\ q_j))\ d(ln\ q_j)] / \\
&\quad [\Sigma_j (\partial(ln\ u) / \partial(ln\ q_j))]\}, \\
(\partial \pi_i / \partial u)\, du &= \pi_i[\partial(ln\ \pi_i) / \partial(ln\ k)]\ \Sigma_j w_j\ d(ln\ q_j).
\end{aligned} \tag{2-22}$$

From $d\pi_i = \pi_i\ d(ln\ \pi_i)$, we get the logarithmic version of the RIDS model,

$$\begin{aligned}
\pi_i\ d(ln\ \pi_i) &= \pi_i[\partial(ln\ \pi_i) / \partial(ln\ k)]\ \Sigma_j w_j\ d(ln\ q_j) + \pi_i[\Sigma_j(\partial(ln\ \pi_i) / \partial(ln\ q_j))\ d(ln\ q_j)], \\
d(ln\ \pi_i) &= [\partial(ln\ \pi_i) / \partial(ln\ k)]\ \Sigma_j w_j\ d(ln\ q_j) + \Sigma_j [\partial(ln\ \pi_i) / \partial(ln\ q_j)]\ d(ln\ q_j), \\
d(ln\ \pi_i) &= \zeta_i\ d(ln\ Q) + \Sigma_j \xi_{ij}\ d(ln\ q_j),
\end{aligned} \tag{2-23}$$

where

$$\zeta_i = \partial(ln\ \pi_i) / \partial(ln\ k) \qquad \text{(the scale elasticity),} \tag{2-24}$$

$$\xi_{ij} = \partial(ln\ \pi_i) / \partial(ln\ q_j) \qquad \text{(the compensated quantity elasticity).} \tag{2-25}$$

In order to satisfy the symmetry condition, we premultiply both sides by w_i. The RIDS model now can be written as

$$w_i\ d(ln\ \pi_i) = w_i\zeta_i\ d(ln\ Q) + \Sigma_j\ w_i\xi_{ij}\ d(ln\ q_j),$$

$$w_i\, d(\ln \pi_i) = h_i\, d(\ln Q) + \Sigma_j\, h_{ij}\, d(\ln q_j), \tag{2-26}$$

where

$$h_i = w_i \zeta_i, \tag{2-27}$$

$$h_{ij} = w_i \xi_{ij}. \tag{2-28}$$

As $dq = kq^*$, the scale elasticity, ζ_i, is h_i / w_i. The compensated quantity elasticity (flexibility), ξ_{ij}, is h_{ij} / w_i with the following properties.

First, the adding-up conditions are

$$\Sigma_i\, h_i = -\, 1, \tag{2-29}$$

$$\Sigma_i\, h_{ij} = 0. \tag{2-30}$$

Second, the homogeneity condition is

$$\Sigma_j\, h_{ij} = 0. \tag{2-31}$$

Third, the symmetry condition is

$$h_{ij} = h_{ji} \qquad \text{(Antonelli symmetry).} \tag{2-32}$$

Fourth, the negativity condition is

$$\Sigma_i\, \Sigma_j\, x_i\, w_i\, h_{ij}\, x_j < 0 \qquad x_i,\, x_j \neq \text{constant.} \tag{2-33}$$

The second functional form of the inverse demand system is the Laitinen and Theil's Inverse Demand System (La-Theil). Following Laitinen and Theil (1979), we describe the consumer's preferences as $g(u, q)$, where $g(u, q)$ is the distance function which is linearly homogeneous in q. The Antonelli matrix is

$$A = [\alpha_{ij}],\ \alpha_{ij} = \partial^2 g \,/\, \partial(p_i q_i)\partial(p_j q_j). \tag{2-34}$$

From this Antonelli matrix, we can find the inverse demand system,

$$d[\ln (p_i/P)] = \zeta_i\, d(\ln Q) + \Sigma_j\, \xi_{ij}\, d(\ln q_j) + \Sigma_j\, w_j\, d(\ln q_j),$$
$$d[\ln (p_i/P)] = (\zeta_i + 1)\, d(\ln Q) + \Sigma_j\, \xi_{ij}\, d(\ln q_j).$$

We also can get the logarithmic version of the La-Theil model from the logarithmic version of the RIDS model (Equation 2-23) by adding $d(ln\ Q)$ to both sides,

$$d(ln\ \pi_i) + d(ln\ Q) = (\zeta_i + 1)\ d(ln\ Q) + \Sigma_j\ \xi_{ij}\ d(ln\ q_j),$$
$$d(ln\ p_i) - d(ln\ P) - d(ln\ Q) + d(ln\ Q) = (\zeta_i + 1)\ d(ln\ Q) + \Sigma_j\ \xi_{ij}\ d(ln\ q_j),$$
$$d[ln\ (p_i/P)] = (\zeta_i + 1)\ d(ln\ Q) + \Sigma_j\ \xi_{ij}\ d(ln\ q_j). \quad (2\text{-}35)$$

In order to satisfy the symmetry condition, we premultiply both sides of Equation 2-35 by w_i, so the La-Theil model is

$$w_i\ d[ln\ (p_i/P)] = w_i(\zeta_i + 1)\ d(ln\ Q) + \Sigma_j\ w_i\xi_{ij}\ d(ln\ q_j),$$
$$w_i\ d[ln\ (p_i/P)] = (w_i\zeta_i + w_i)\ d(ln\ Q) + \Sigma_j\ h_{ij}\ d(ln\ q_j),$$
$$w_i\ d[ln\ (p_i/P)] = (h_i + w_i)\ d(ln\ Q) + \Sigma_j\ h_{ij}\ d(ln\ q_j),$$
$$w_i\ d[ln\ (p_i/P)] = b_i\ d(ln\ Q) + \Sigma_j\ h_{ij}\ d(ln\ q_j), \quad (2\text{-}36)$$

where

$$b_i = h_i + w_i. \quad (2\text{-}37)$$

The coefficients of the La-Theil model also satisfy the neoclassical restrictions with parameter h_{ij}, which can be defined by Equation 2-27. Having the same properties as parameter h_{ij} in the RIDS model (Equation 2-26), the adding-up condition requires

$$\Sigma_i\ b_i = 0. \quad (2\text{-}38)$$

The third functional form of the inverse demand system is the Almost Ideal Inverse Demand System (AIIDS), which can be obtained from the distance function,

$$ln\ g(u, q) = (1 - u)\ ln\ \mathrm{a}(q) - u\ ln\ \mathrm{b}(q), \quad (2\text{-}39)$$

where

$$ln\ a(q) = \alpha_0 + \Sigma_k\ \alpha_k\ ln\ q_k + (1/2)\Sigma_k\Sigma_j\ \gamma_{kj}^*\ ln\ q_k\ ln\ q_j, \quad (2\text{-}40)$$

$$ln\ b(q) = ln\ a(q) + \beta_0\Pi_k\ q_k^{\beta}. \quad (2\text{-}41)$$

The AIIDS cost function is written as

$$ln\ g(u, q) = (1 - u)\ ln\ a(q) + u[ln\ a(q) + \beta_0\Pi_k\ q_k^{\beta}],$$
$$ln\ g(u, q) = ln\ a(q) + u\beta_0\Pi_k\ q_k^{\beta},$$

$$ln\, g(u, q) = \alpha_0 + \Sigma_k \alpha_k\, ln\, q_k + (1/2)\Sigma_k \Sigma_j \gamma_{kj}^*\, ln\, q_k\, ln\, q_j + u\beta_0 \Pi_k\, q_k^{\beta}, \tag{2-42}$$

where α_i, γ_{ij}^*, β_i are the parameters. By using the derivative property of the cost function, $p_i = \partial g / \partial q_i$ and $m = g(u^*, q)$, the budget share of good i can be written as

$$\begin{aligned} w_i &= p_i q_i / m \\ w_i &= (\partial g / \partial p_i) p_i / g \\ w_i &= \partial(ln\, g) / \partial(ln\, p_i). \end{aligned} \tag{2-43}$$

Hence, from Equation 2-42, the logarithmic differentiation gives the budget shares as a function of prices and utility,

$$w_i = \alpha_i + \Sigma_j \gamma_{ij}\, ln\, q_j + b_i u \beta_0 \Pi_k\, q_k^{\beta}, \tag{2-44}$$

where $\gamma_{ij} = (1/2)(\gamma_{ij}^* + \gamma_{ji}^*)$.

As an approximation, we can replace $u\beta_0 \Pi_k\, q_k^{\beta}$ with $\Sigma_i\, w_i\, ln\, q_i$. The differential form of the AIIDS model is

$$\begin{aligned} dw_i &= b_i \Sigma_i w_i\, d(ln\, q_i) + \Sigma_j \gamma_{ij}\, d(ln\, q_j), \\ dw_i &= b_i\, d(ln\, Q) + \Sigma_j \gamma_{ij}\, d(ln\, q_j). \end{aligned} \tag{2-45}$$

There are four properties for the coefficients of the AIIDS model that satisfy the neoclassical restrictions. First, the adding-up conditions are

$$\Sigma_i \gamma_{ij} = 0, \tag{2-46}$$

$$\Sigma_i b_i = 0. \tag{2-47}$$

Second, the homogeneous of degree zero is

$$\Sigma_j \gamma_{ij} = 0. \tag{2-48}$$

Third, the Slutsky symmetry is

$$\gamma_{ij} = \gamma_{ji}. \tag{2-49}$$

Fourth, the negativity condition is

$$\Sigma_i \Sigma_j\ x_i\, \gamma_{ij}\, x_j < 0 \qquad x_i,\ x_j \neq \text{constant}. \tag{2-50}$$

In addition, from the logarithmic version of the La-Theil model (Equation 2-35), we can get the logarithmic version of the AIIDS model by adding $d(ln\ q_i) - d(ln\ Q)$ to both sides,

$$d(ln\ p_i) - d(ln\ P) + d(ln\ q_i) - d(ln\ Q) = (\zeta_i + 1)\ d(ln\ Q) + \Sigma_j\ \xi_{ij}\ d(ln\ q_j) + d(ln\ q_i) - d(ln\ Q),$$
$$d(ln\ \pi_i) + d(ln\ q_i) = (\zeta_i + 1)\ d(ln\ Q) + \Sigma_j\ (\xi_{ij} + \delta_{ij} - w_j)\ d(ln\ q_j),$$
$$d(ln\ w_i) = (\zeta_i + 1)\ d(ln\ Q) + \Sigma_j\ (\xi_{ij} + \delta_{ij} - w_j)\ d(ln\ q_j).$$

We also can derive the logarithmic version of the AIIDS model by adding $d(ln\ q_i)$ on both sides of the logarithmic version of the RIDS model (Equation 2-23),

$$d(ln\ \pi_i) + d(ln\ q_i) = \zeta_i\ d(ln\ Q) + \Sigma_j\ \xi_{ij}\ d(ln\ q_j) + d(ln\ q_i),$$
$$d(ln\ \pi_i) + d(ln\ q_i) = \zeta_i\ d(ln\ Q) + d(ln\ Q) + \Sigma_j\ \xi_{ij}\ d(ln\ q_j) + d(ln\ q_i) - d(ln\ Q),$$
$$d(ln\ w_i) = (\zeta_i + 1)\ d(ln\ Q) + \Sigma_j\ (\xi_{ij} + \delta_{ij} - w_j)\ d(ln\ q_j). \quad (2\text{-}51)$$

In order to satisfy the symmetry condition, we premultiply both sides of Equation 2-51 by w_i, so the AIIDS model is

$$w_i\ d(ln\ w_i) = (w_i\zeta_i + w_i)\ d(ln\ Q) + \Sigma_j\ (w_i\xi_{ij} + w_i\delta_{ij} - w_iw_j)\ d(ln\ q_j),$$
$$dw_i = b_i\ d(ln\ Q) + \Sigma_j\ \gamma_{ij}\ d(ln\ q_j),$$

which is the same as Equation 2-45 and

$$\gamma_{ij} = w_i\xi_{ij} + w_i\delta_{ij} - w_iw_j. \quad (2\text{-}52)$$

The last functional form of the inverse demand system is the Rotterdam Almost Ideal Inverse Demand System (RAIIDS). We can get the logarithmic version of the RAIIDS model by subtracting $d(ln\ Q)$ from both sides of the logarithmic version of the AIIDS model (Equation 2-51),

$$d(ln\ w_i) - d(ln\ Q) = (\zeta_i + 1)\ d(ln\ Q) + \Sigma_j\ (\xi_{ij} + \delta_{ij} - w_j)\ d(ln\ q_j) - d(ln\ Q),$$
$$d(ln\ w_i) - d(ln\ Q) = \zeta_i\ d(ln\ Q) + \Sigma_j\ (\xi_{ij} + \delta_{ij} - w_j)\ d(ln\ q_j).$$

We also can get the logarithmic version of the RAIIDS model by adding $d(ln\ q_i) - d(ln\ Q)$ to both sides of the logarithmic version of the RIDS model (Equation 2-23),

$$d(ln\ \pi_i) + d(ln\ q_i) - d(ln\ Q) = \zeta_i\ d(ln\ Q) + \Sigma_j\ \xi_{ij}\ d(ln\ q_j) + d(ln\ q_i) - d(ln\ Q),$$
$$d(ln\ \pi_i) + d(ln\ q_i) - d(ln\ Q) = \zeta_i\ d(ln\ Q) + \Sigma_j\ (\xi_{ij} + \delta_{ij} - w_j)\ d(ln\ q_j),$$

$$d(ln\, w_i) - d(ln\, Q) = \zeta_i\, d(ln\, Q) + \Sigma_j\, (\xi_{ij} + \delta_{ij} - w_j)\, d(ln\, q_j). \tag{2-53}$$

In order to satisfy the symmetry condition, we premultiply both sides of Equation 2-53 by w_i, so the RAIIDS model is

$$w_i[d(ln\, w_i) - d(ln\, Q)] = w_i\zeta_i\, d(ln\, Q) + \Sigma_j\, (w_i\xi_{ij} + w_i\delta_{ij} - w_iw_j)\, d(ln\, q_j),$$
$$dw_i - w_i\, d(ln\, Q) = h_i\, d(ln\, Q) + \Sigma_j\, \gamma_{ij}\, d(ln\, q_j). \tag{2-54}$$

By using our new formulation, the properties of parameter h_i, which can be defined by Equation 2-27, are equivalent to the ones in the RIDS model (Equation 2-26), and the properties of parameter γ_{ij}, which can be defined by Equation 2-37, are equivalent to the ones in the AIIDS model (Equation 2-45). As a result, the RAIIDS model has the RIDS scale effects and the AIIDS quantity effects. On the other hand, the La-Theil model has the AIIDS scale effects and the RIDS quantity effects.

Scale and Quantity Comparative Statics

We can examine relations for inverse demands by following Anderson (1980) to express price as a function of quantities and total expenditure,

$$p_i = f(q, m), \tag{2-55}$$

and normalized prices, $\pi_i = p_i\, /\, m$, as a function of quantities,

$$\pi_i = f(q, 1) = f^i(q). \tag{2-56}$$

As it is true about quantity elasticities of prices being equivalent to those about quantity elasticities of normalized prices, we confine our discussion to normalized prices in what follows. Quantity elasticities are the natural analogs for inverse demands of price elasticities, μ_{ij}, in direct demands. They tell how much price i must change to induce the consumer to absorb marginally more of good j. The quantity elasticity of good i with respect to good j is defined as

$$\psi_{ij} = [\partial f^i(q)\, /\, \partial q_j][q_j\, /\, f^i(q)]. \tag{2-57}$$

When dealing with inverse demands, an interesting question is: how much will price i change in response to a proportionate increase in all commodities, or how do prices change as you increase the scale of the commodity vector along a ray radiating from the origin through a commodity vector? We formalize this notion for marginal increases in the scale of consumption by defining the scale elasticity to derive restrictions relating to quantity and scale elasticities. These restrictions show that the scale elasticity is analogous to total expenditure elasticity, η_i, in direct demands. Let q^* be a reference vector in commodity space so that we can represent the consumption vector of interest as $q = kq^*$, where k is a scalar. We can express the inverse demands as

$$\pi_i = f^i(kq^*) = g^i(k, q^*). \tag{2-58}$$

The scale elasticity of good i is defined as

$$\zeta_i = [\partial g^i(k, q^*) / \partial k][k / g^i(k, q^*)]. \tag{2-59}$$

Quantity and scale elasticities obey restrictions that are directly analogous to restrictions for direct demands. For the homogeneity of degree zero restriction, we can write

$$\begin{aligned} \zeta_i &= \Sigma_j [\partial f^i(q) / \partial q_j] q_j^* [k / f^i(q)], \\ \zeta_i &= \Sigma_j [\partial f^i(q) / \partial q_j][q_j / f^i(q)], \\ \zeta_i &= \Sigma_j \psi_{ij}, \end{aligned} \tag{2-60}$$

which is analogous to $\Sigma_j \mu_{ij} = -\eta_i$ in the direct demand system.

For the adding-up conditions, we start by writing the budget equation, $w_i = \pi_i q_i$, as

$$w_i = f^i(q)\, q_i. \tag{2-61}$$

From $\Sigma_i w_i = 1$, we get

$$\Sigma_i f^i(q)\, q_i = 1. \tag{2-62}$$

Differentiating with respect to q_j, we have

$$\Sigma_i [\partial f^i(q) / \partial q_j] q_i + f^i(q) = 0,$$

$$\Sigma_i [\partial f^i(q) / \partial q_j] q_i = -f^i(q).$$

By multiplying both sides by q_j, we obtain

$$\Sigma_i [\partial f^i(q) / \partial q_j][q_j / f^i(q)] f^i(q)\, q_i = -f^i(q)\, q_j.$$

As $\psi_{ij} = [\partial f^i(q) / \partial q_j][q_j / f^i(q)]$ and $w_i = f^i(q)\, q_i$, we have

$$\Sigma_i\ \psi_{ij} w_i = -\, w_j, \tag{2-63}$$

which is analogous to the Cournot aggregation, $\Sigma_i\ w_i \mu_{ij} = -\ w_j$. Next, the analogous to the Engel aggregation, $\Sigma_i\ w_i \eta_i = 1$, is obtained by

$$\Sigma_i\ w_i\ \Sigma_j\ \psi_{ij} = -\ \Sigma_j\ w_j.$$

As $\zeta_i = \Sigma_j\ \psi_{ij}$ and $\Sigma_i\ w_i = 1$, we get

$$\Sigma_i\ w_i \zeta_i = -\ 1. \tag{2-64}$$

Scale and quantity elasticities are the natural concepts of uncompensated elasticities for inverse demands. We derive the constant-utility-quantity elasticities, or compensated-quantity elasticities, from the transportation function, $T(q, u)$, which is dual to the cost function and satisfies

$$U[q^* / T(q^*, u^*)] = u^* \tag{2-65}$$

for all feasible q^* and u^*. The transformation informs how much a particular consumption vector must be divided to place the consumer on some particular indifference curve. By differentiating with respect to goods, we get the constant utility or compensated inverse demands,

$$\pi_i = f^{i*}(q, u) = \partial T(q, u) / \partial q_i. \tag{2-66}$$

These price functions give the levels of normalized prices that induce consumers to choose a consumption bundle that is along the ray passing through q and that gives utility u. The constant utility quantity effects, or the Antonelli substitution effects, state the

amounts normalized prices change with respect to a marginal change of reference consumption q_j, keeping the consumer on the same indifference level. We can express the Antonelli substitution effects in elasticity form, which is analogous to the compensated-price elasticity, ε_{ij}. The constant-utility-quantity elasticity of good i with respect to good j is defined as

$$\xi_{ij} = [\partial^2 T(q, u) / \partial q_i\, q_j]\{q_j / [\partial T(q, u) / \partial q_i]\},$$
$$\xi_{ij} = (\partial \pi_i / \partial q_j)(q_j / \pi_i). \tag{2-67}$$

$T(q, u)$ is homogeneous of degree one in q, and $f^{i*}(q, u)$ is homogeneous of degree zero in q. From the direct application of Euler's theorem, we get

$$\Sigma_j\, \xi_{ij} = 0, \tag{2-68}$$

which is analogous to the restriction, $\Sigma_j\, \varepsilon_{ij} = 0$. From the properties of the transformation function, which include the decrease in u, and the increase, linear-homogeneous, and concave in q, the matrix of Antonelli effects is negative semidefinite. This implies $\delta_{ij} < 0$, which can be called the Law of Inverse Demand. Next, we describe the implicit compensation scheme to derive the inverse demand equation, which is analogous of the Slutsky equation. The total change in prices associated with an increase in one quantity can be decomposed, as total effect equals the summation of the substitution effect and the scale effect.

Now, consider a marginal change in the price in response to a marginal change in relative quantity and in scale. By totally differentiating $\pi_i = g^i(k, q^*)$, we get

$$d\pi_i = [\partial g^i(k, q^*) / \partial q_j^*]\, dq_j^* + [\partial g^i(k, q^*) / \partial k]\, dk. \tag{2-69}$$

The change in scale must compensate for the change in q_j* so as to leave the utility unchanged, $du = 0$. With $\pi_i = (\partial u / \partial q_i) / \Sigma_j (\partial u/\partial q_j)q_j$, we get

$$du = \Sigma_i (\partial u / \partial q_i^*)q_i^* \, dk + (\partial u / \partial q_j^*)k \, dq_j^* = 0, \tag{2-70}$$

$$dk = -[(\partial u / \partial q_j^*) / \Sigma_i (\partial u / \partial q_i^*)q_i^*]k \, dq_j^* = -\pi_j \, k \, dq_j^*. \tag{2-71}$$

From Equations 2-69, 2-70, and 2-71, we get

$$d\pi_i = [\partial g^i(k, q^*) / \partial q_j^*] \, dq_j^* + [\partial g^i(k, q^*) / \partial k](-\pi_j \, k \, dq_j^*),$$
$$d\pi_i / dq_j^* = [\partial g^i(k, q^*) / \partial q_j^*] - [\partial g^i(k, q^*) / \partial k]\pi_j \, k.$$

By multiplying both sides by (q_j^* / π_i), we get

$$(d\pi_i / dq_j^*)(q_j^* / \pi_i) = (\partial \pi_i / \partial q_j^*)(q_j^* / \pi_i) - (\partial \pi_i / \partial k)\pi_j \, k(q_j^* / \pi_i),$$
$$(d\pi_i / dq_j^*)(q_j^* / \pi_i) = (\partial \pi_i / \partial q_j^*)(q_j^* / \pi_i) - (\partial \pi_i / \partial k)(k / \pi_i)(\pi_j \, q_j^*). \tag{2-72}$$

As $w_j = \pi_j \, q_j$, $\xi_{ij} = (d\pi_i / dq_j)(q_j / \pi_i)$, $\zeta_i = (\partial \pi_i / \partial k)(k / \pi_i)$ and $\psi_{ij} = (\partial \pi_i / \partial q_j)(q_j / \pi_i)$, it is convenient to express this in elasticity terms,

$$\xi_{ij} = \psi_{ij} - \zeta_i w_j. \tag{2-73}$$

This states the Antonelli substitution effects in terms of scale and uncompensated-quantity changes. It is fully analogous to the Slutsky equation (Equation 2-5) of standard theory,

$$(\partial h_i / \partial p_j)(p_j / h_i) = (\partial q_i / \partial p_j)(p_j / q_i) + (\partial q_i / \partial m)(m / q_i)(p_j q_j / m)$$

$$\varepsilon_{ij} = \mu_{ij} + \eta_i w_j,$$

where $h_i(p, u)$ is the Hicksian compensated demand function, which allows the demand analyst working with inverse demands to compute compensated elasticities from the uncompensated elasticities directly (without being obliged to explicitly consider the transformation function or compensated inverse demands). Finally, from $\Sigma_i \, \psi_{ij} w_i = -w_j$ and $\Sigma_i \, w_i \zeta_i = -1$, we can derive the analog to Slutsky aggregation

$$\Sigma_i \, w_i \xi_{ij} = \Sigma_i \, w_i \psi_{ij} - \Sigma_i \, w_i \zeta_i w_j,$$
$$\Sigma_i \, w_i \xi_{ij} = -w_j - (-1)w_j,$$
$$\Sigma_i \, w_i \xi_{ij} = 0. \tag{2-74}$$

The symmetry of $d\pi_i / dq_i^*$ implies that compensated-quantity cross derivatives between any two goods, i and j, must satisfy $d\pi_i / dq_j^* = d\pi_j / dq_i^*$. The symmetry property reflects the fact that the cross derivatives of a function are equal. We also get the symmetry of the matrix of Antonelli substitution effects from this symmetry property,

$$d\pi_i / dq_j^* = d\pi_j / dq_i^*.$$

By multiplying by $q_i^* q_j^*$ on both sides, we get

$$(d\pi_i / dq_j^*)(q_i^* q_j^*) = (d\pi_j / dq_i^*)(q_i^* q_j^*),$$
$$(d\pi_i / dq_j^*)(q_i^* q_j^*)(\pi_i / \pi_i) = (d\pi_j / dq_i^*)(q_i^* q_j^*)(\pi_j / \pi_j),$$
$$(\pi_i q_i^*)(d\pi_i / dq_j^*)(q_j^* / \pi_i) = (\pi_j q_j^*)(d\pi_j / dq_i^*)(q_i^* / \pi_j).$$

As $w_i = \pi_i q_i$, $\xi_{ij} = (d\pi_i / dq_j)(q_j / \pi_i)$, we get Antonelli symmetry,

$$w_i\xi_{ij} = w_j\xi_{ji}, \tag{2-75}$$

which is analogous to Slutsky symmetry, $w_i\varepsilon_{ij} = w_j\varepsilon_{ji}$ (Equation 2-12).

From the AIIDS model, we can prove for the adding-up condition, Equation 2-46, by using the summation of Equation 2-52 over i ($\Sigma_i \gamma_{ij} = \Sigma_i w_i\xi_{ij} + \Sigma_i w_i\delta_{ij} - w_j \Sigma_i w_i$). As $\Sigma_i w_i\xi_{ij} = 0$, $w_j = \Sigma_i w_i\delta_{ij}$, and $\Sigma_i w_i = 1$, we get Equation 2-46 ($\Sigma_i \gamma_{ij} = 0$). The proof for Equation 2-47 can be obtained by working with Equation 2-37 ($\Sigma_i b_i = \Sigma_i w_i\zeta_i + \Sigma_i w_i$). As $\Sigma_i w_i\zeta_i = -1$ and $\Sigma_i w_i = 1$, we get Equation 2-47 ($\Sigma_i b_i = 0$). Next, we prove the homogeneity of degree zero, Equation 2-48, by using the summation of Equation 2-52 over j ($\Sigma_j \gamma_{ij} = w_i \Sigma_j \xi_{ij} + \Sigma_j w_i\delta_{ij} - w_i \Sigma_j w_j$). As $\Sigma_j \xi_{ij} = 0$, $w_i = \Sigma_j w_i\delta_{ij}$ and $\Sigma_j w_j = 1$, we get Equation 2-48 ($\Sigma_j \gamma_{ij} = 0$). We also prove the Antonelli symmetry, Equation 2-49, by working with Equation 2-52 ($\gamma_{ij} = w_i\xi_{ij} + w_i\delta_{ij} - w_iw_j$). As $w_i\xi_{ij} = w_j\xi_{ji}$ and $w_i\delta_{ij} = w_j\delta_{ji}$, we get $\gamma_{ij} = w_j\xi_{ji} + w_j\delta_{ji} - w_iw_j$, which means $\gamma_{ij} = \gamma_{ji}$ (Equation 2-49).

Econometric Model Development

For the purpose of estimating, operator d is the log-change operator; that is, if x is any variable and x_{it} is its value in year t, then

$$d(ln\ x_i) = \Delta(ln\ x_{it}) = ln\ x_{it} - ln\ x_{i\,t\text{-}1} = ln\ (x_{it} / x_{i\,t\text{-}1}). \tag{2-76}$$

For the budget share, Barten (1993) replaced w_i by the moving average, w^*_{it}, where

$$w^*_{it} = (w_{i,t\text{-}1} + w_{it}) / 2. \tag{2-77}$$

As a result, each functional form generates different elasticities. The big disadvantage is on the coefficients of the demand systems. To solve this problem, we proposed a new formulation by using the mean of the budget share, $\overline{w}_i$, where

$$\overline{w}_i = \Sigma_t w_{it} / T, \tag{2-78}$$

where $t = 1, \ldots, T$. By using this formulation, each coefficient of the demand systems is a function of $\overline{w}_i$ instead of w^*_{it}, and the calculated elasticities are expected to be unchanged across the functional forms.

First, by replacing $d(ln\ \pi_i)$ with $\Delta(ln\ \pi_{it})$, $d(ln\ Q)$ with $\Delta(ln\ Q_t)$, and $d(ln\ q_j)$ with $\Delta(ln\ q_{jt})$ in Equation 2-26, the econometric model development for the RIDS model can be written as

$$\begin{aligned} \overline{w}_i\ \Delta(ln\ \pi_{it}) &= \overline{w}_i\ \zeta_i\ \Delta(ln\ Q_t) + \Sigma_j\ \overline{w}_i\ \xi_{ij}\ \Delta(ln\ q_{jt}) + v_{it}, \\ \overline{w}_i\ \Delta(ln\ \pi_{it}) &= h_i\ \Delta(ln\ Q_t) + \Sigma_j\ h_{ij}\ \Delta(ln\ q_{jt}) + v_{it}, \end{aligned} \tag{2-79}$$

where

$$h_i = \overline{w}_i\ \zeta_i, \tag{2-80}$$

$$h_{ij} = \overline{w}_i\ \xi_{ij}. \tag{2-81}$$

Second, we get the econometric model development for the La-Theil model (which has the RIDS scale coefficients and the AIIDS quantity coefficients) by adding $\overline{w}_i\,\Delta(ln\, Q_t)$ on both sides of the RIDS model (Equation 2-79),

$$\begin{aligned}
&\overline{w}_i\,\Delta(ln\,\pi_{it}) + \overline{w}_i\,\Delta(ln\,Q_t) = (\overline{w}_i\,\zeta_i + \overline{w}_i\,)\,\Delta(ln\,Q_t) + \Sigma_j\,\overline{w}_i\,\xi_{ij}\,\Delta(ln\,q_{jt}) + v_{it},\\
&\overline{w}_i\,[\Delta(ln\,\pi_{it}) + \Delta(ln\,Q_t)] = b_i\,\Delta(ln\,Q_t) + \Sigma_j\,h_{ij}\,\Delta(ln\,q_{jt}) + v_{it},\\
&\overline{w}_i\,\Delta[ln\,(p_{it}\,/\,P_t)] = b_i\,\Delta(ln\,Q_t) + \Sigma_j\,h_{ij}\,\Delta(ln\,q_{jt}) + v_{it},
\end{aligned} \tag{2-82}$$

where

$$\overline{w}_i\,\Delta[ln\,(p_{it}\,/\,P_t)] = \overline{w}_i\,\,[\Delta(ln\,p_{it}) - \Delta(ln\,P_t)] = \overline{w}_i\,[\,\Delta(ln\,\pi_{it}) + \Delta(ln\,Q_t)]. \tag{2-83}$$

Next, we consider the Almost Ideal Inverse Demand System. We introduce parameter $\Delta(ln\,Q_t^*)$ for the AIIDS model, where

$$\Delta(ln\,Q_t^*) = \Sigma_j\,\overline{w}_j\,\Delta(ln\,q_{jt}). \tag{2-84}$$

By using this parameter, the coefficients of the AIIDS will be the function of $\overline{w}_j$, not the function of w_{jt}^*. We get the econometric model development for the AIIDS model from Equation 2-45 by replacing dw_i with dw_{it}, $d(ln\,Q)$ with $\Delta(ln\,Q_t)$, and $d(ln\,q_j)$ with $\Delta(ln\,q_{jt})$,

$$\begin{aligned}
&dw_{it} = (\overline{w}_i\,\zeta_i + \overline{w}_i\,)\,\Delta(ln\,Q_t) + \Sigma_j\,(\overline{w}_i\,\xi_{ij} + \overline{w}_i\,\delta_{ij} - \overline{w}_i\,w_{jt}^*\,)\,\Delta(ln\,q_{jt}) + v_{it},\\
&dw_{it} + \Sigma_j\,\overline{w}_i\,w_{jt}^*\,\Delta(ln\,q_{jt}) - \Sigma_j\,\overline{w}_i\,\overline{w}_j\,\Delta(ln\,q_{jt})\\
&= (\overline{w}_i\,\zeta_i + \overline{w}_i\,)\,\Delta(ln\,Q_t) + \Sigma_j\,(\overline{w}_i\,\xi_{ij} + \overline{w}_i\,\delta_{ij} - \overline{w}_i\,\overline{w}_j\,)\,\Delta(ln\,q_{jt}) + v_{it},\\
&dw_{it} + \overline{w}_i\,[\Delta(ln\,Q_t) - \Delta(ln\,Q_t^*\,)] = b_i\,\Delta(ln\,Q_t) + \Sigma_j\,\gamma_{ij}\,\Delta(ln\,q_{jt}) + v_{it},\\
&\overline{w}_i\,[\Delta(ln\,\pi_{it}) + \Delta(ln\,q_{it}) + \Delta(ln\,Q_t) - \Delta(ln\,Q_t^*\,)]\\
&= b_i\,d(ln\,Q_t) + \Sigma_j\,\gamma_{ij}\,\Delta(ln\,q_{jt}) + v_{it},
\end{aligned} \tag{2-85}$$

where

$$dw_{it} = \overline{w}_i\,\Delta(ln\,w_{it}) = \overline{w}_i\,[\Delta(ln\,\pi_{it}) + \Delta(ln\,q_{it})], \tag{2-86}$$

$$b_i = \overline{w}_i\,\zeta_i + \overline{w}_i\,, \tag{2-87}$$

$$\gamma_{ij} = \overline{w}_i\,\xi_{ij} + \overline{w}_i\,\delta_{ij} - \overline{w}_i\,\overline{w}_j\,. \tag{2-88}$$

For the last functional form, we get the econometric model development for the RAIIDS model that has the AIIDS scale coefficients and the RIDS quantity coefficients by subtracting $\overline{w}_i\, \Delta(ln\, Q_t)$ on both sides of the AIIDS model (Equation 2-85),

$$dw_{it} + \overline{w}_i\, [\Delta(ln\, Q_t) - \Delta(ln\, Q_t^*)] - \overline{w}_i\, \Delta(ln\, Q_t)$$
$$= \overline{w}_i\, \zeta_i\, \Delta(ln\, Q_t) + \Sigma_j\, (\overline{w}_i\, \xi_{ij} + \overline{w}_i\, \delta_{ij} - \overline{w}_i\, \overline{w}_j)\, \Delta(ln\, q_{jt}) + v_{it},$$
$$dw_{it} - \overline{w}_i\, \Delta(ln\, Q_t^*) = h_i\, \Delta(ln\, Q_t) + \Sigma_j\, \gamma_{ij}\, \Delta(ln\, q_{jt}) + v_{it},$$
$$\overline{w}_i\, [\Delta(ln\, \pi_{it}) + \Delta(ln\, q_{it}) - \Delta(ln\, Q_t^*)] = h_i\, \Delta(ln\, Q_t) + \Sigma_j\, \gamma_{ij}\, \Delta(ln\, q_{jt}) + v_{it}. \tag{2-89}$$

From the coefficients of each functional form of inverse demand system, we can calculate the scale elasticity and the compensated quantity elasticity by using the following equations:

$$\zeta_i = h_i\, /\, \overline{w}_i = (b_i\, /\, \overline{w}_i) - 1, \tag{2-90}$$

$$\xi_{ij} = h_{ij}\, /\, \overline{w}_i = (\gamma_{ij}\, /\, \overline{w}_i) + \overline{w}_j - \delta_{ij}. \tag{2-91}$$

The uncompensated quantity elasticity can be calculated by using the Antonelli equation,

$$\psi_{ij} = \xi_{ij} + \zeta_i \overline{w}_j\, . \tag{2-92}$$

Because functional forms of the demand systems can be related to each other theoretically, we can show that standard errors are unchanged across the functional forms of the inverse demand system. The standard error can be calculated from the disturbance,

$$v_{it} = y_{it} - \tilde{y}_{it} = \beta_i x_{it} - \tilde{\beta}_i x_{it}, \tag{2-93}$$

where $\tilde{y}_{it}$ is the estimation of the dependent or explained variable, y_{it}, $\tilde{\beta}_i$ is the estimation of the coefficient, β_i ,and x_{it} is the independent or explanatory variable. The disturbance for the RIDS model (Equation 2-26) is

$$v_{it} = [h_i\, \Delta(ln\, Q_t) + \Sigma_j\, h_{ij}\, \Delta(ln\, q_{jt})] - [\tilde{h}_i\, \Delta(ln\, Q_t) + \Sigma_j\, \tilde{h}_{ij}\, \Delta(ln\, q_{jt})],$$
$$v_{it} = (h_i - \tilde{h}_i)\, \Delta(ln\, Q_t) + \Sigma_j\, (h_{ij} - \tilde{h}_{ij})\Delta(ln\, q_{jt}). \tag{2-94}$$

The disturbance for the La-Theil model (Equation 2-36) is

$$v_{it} = [b_i\, \Delta(ln\, Q_t) + \Sigma_j\, h_{ij}\, \Delta(ln\, q_{jt})] - [\widetilde{b}_i\, \Delta(ln\, Q_t) + \Sigma_j\, \widetilde{h}_{ij}\, \Delta(ln\, q_{jt})],$$
$$v_{it} = (b_i - \widetilde{b}_i)\Delta(ln\, Q_t) + \Sigma_j\, (h_{ij} - \widetilde{h}_{ij})\Delta(ln\, q_{jt}). \tag{2-95}$$

The disturbance for the model AIIDS (Equation 2-45) is

$$v_{it} = [b_i\, \Delta(ln\, Q_t) + \Sigma_j\, \gamma_{ij}\, \Delta(ln\, q_{jt})] - [\widetilde{b}_i\, \Delta(ln\, Q_t) + \Sigma_j\, \widetilde{\gamma}_{ij}\, \Delta(ln\, q_{jt})],$$
$$v_{it} = (b_i - \widetilde{b}_i)\Delta(ln\, Q_t) + \Sigma_j\, (\gamma_{ij} - \widetilde{\gamma}_{ij})\Delta(ln\, q_{jt}). \tag{2-96}$$

The disturbance for the RAIIDS model (Equation 2-54) is

$$v_{it} = [h_i\, \Delta(ln\, Q_t) + \Sigma_j\, \gamma_{ij}\, \Delta(ln\, q_{jt})] - [\widetilde{h}_i\, \Delta(ln\, Q_t) + \Sigma_j\, \widetilde{\gamma}_{ij}\, \Delta(ln\, q_{jt})],$$
$$v_{it} = (h_i - \widetilde{h}_i)\, \Delta(ln\, Q_t) + \Sigma_j\, (\gamma_{ij} - \widetilde{\gamma}_{ij})\Delta(ln\, q_{jt}). \tag{2-97}$$

From the coefficients of these four functional forms of inverse demand system, we can show that

$$h_i - \widetilde{h}_i = \overline{w}_i\, \zeta_i - \overline{w}_i\, \widetilde{\zeta}_i = \overline{w}_i\, (\zeta_i - \widetilde{\zeta}_i), \tag{2-98}$$

$$h_{ij} - \widetilde{h}_{ij} = \overline{w}_i\, \xi_{ij} - \overline{w}_i\, \widetilde{\xi}_{ij} = \overline{w}_i\, (\xi_{ij} - \widetilde{\xi}_{ij}), \tag{2-99}$$

$$b_i - \widetilde{b}_i = (\overline{w}_i\, \zeta_i + \overline{w}_i) - (\overline{w}_i\, \widetilde{\zeta}_i + \overline{w}_i) = \overline{w}_i\, (\zeta_i - \widetilde{\zeta}_i), \tag{2-100}$$

$$\gamma_{ij} - \widetilde{\gamma}_{ij} = (\overline{w}_i\, \xi_{ij} + \overline{w}_i\, \delta_{ij} - \overline{w}_i\, \overline{w}_j) - (\overline{w}_i\, \widetilde{\xi}_{ij} + \overline{w}_i\, \delta_{ij} - \overline{w}_i\, \overline{w}_j) = \overline{w}_i\, (\xi_{ij} - \widetilde{\xi}_{ij}), \tag{2-101}$$

where $\widetilde{h}_i$ is the estimation of h_i, $\widetilde{h}_{ij}$ is the estimation of h_{ij}, $\widetilde{b}_i$ is the estimation of b_i, $\widetilde{\gamma}_{ij}$ is the estimation of γ_{ij}, and $\widetilde{\zeta}_i$ and $\widetilde{\xi}_{ij}$ are the estimations of ζ_i and ξ_{ij}, respectively. Consequently, for all functional forms of the inverse demand system, we get the same disturbance,

$$v_{it} = \overline{w}_i\, [(\zeta_i - \widetilde{\zeta}_i)\Delta(ln\, Q_t) + \Sigma_j\, (\xi_{ij} - \widetilde{\xi}_{ij})\Delta(ln\, q_{jt})]. \tag{2-102}$$

Because we get the same disturbance for every functional form of the inverse demand system, we also get the same standard error and log-likelihood value across all functional forms.

Methodology for Demand Analysis

In following Barten (1969) to estimate the inverse demand system, we used the maximum-likelihood method of estimation with constraints imposed. We imposed the homogeneity and symmetry constraints by working with the concentrated log-likelihood function. We estimated every demand equation in the system at the same time by applying the Seemingly Unrelated Regression Estimation. GAUSS (a mathematical and statistical software package), was used to perform the estimation.

There are four scenarios in our study. The first scenario is to estimate each functional form of the inverse demand system by using the mean of the budget share to multiply the logarithmic version of the inverse demand system. The second scenario is to estimate each functional form of the inverse demand system by using the moving average of the budget share to multiply the logarithmic version of the inverse demand system. In addition, the first and second scenarios estimate the inverse demand system by using Barten's estimation method with the homogeneity and symmetry constraints imposed. The third scenario is to estimate the RIDS model by using Barten's unconstrained estimation method. The fourth scenario is to estimate the RIDS model by using Barten's estimation method with the homogeneity constraint imposed.

Results are based on time series data from 1994 to 1998 for four commodities of selected vegetables and fruits, $n = 4$. Weekly wholesale prices and quantity unloads were collected from the Market News Branch of the Fruit and Vegetable Division, Agricultural Marketing Service, United States Department of Agriculture. There are 208 observations

of quantities and prices for each commodity in each market, $T = 208$. The commodities are tomatoes, bell peppers, cucumbers, and strawberries. The markets include Atlanta, New York, Los Angeles, and Chicago.

Seemingly Unrelated Regressions Model

Following Greene (2000), the inverse demand systems can be written as

$$\begin{aligned} y_1 &= XB + \varepsilon_1, \\ y_2 &= XB + \varepsilon_2, \\ &\vdots \\ y_n &= XB + \varepsilon_n, \end{aligned} \tag{2-103}$$

where

$$\varepsilon' = [\varepsilon_1', \varepsilon_2', \dots, \varepsilon_n'], \tag{2-104}$$

$$E[\varepsilon] = 0. \tag{2-105}$$

The disturbance formulation is

$$E[\varepsilon\varepsilon'] = V = \begin{bmatrix} \sigma_{11}I & \sigma_{12}I & \dots & \sigma_{1n}I \\ \sigma_{21}I & \sigma_{22}I & \dots & \sigma_{2n}I \\ \cdot & \cdot & \cdot & \cdot \\ \sigma_{n1}I & \sigma_{n2}I & \dots & \sigma_{nn}I \end{bmatrix}. \tag{2-106}$$

There are n equations and T observations in the data sample. For the demand system, we can apply Seemingly Unrelated Regressions (SUR) with identical regressors or the Generalized Least Square (GLS) with identical regressors,

$$\begin{bmatrix} y_1 \\ y_2 \\ \cdot \\ y_n \end{bmatrix} = \begin{bmatrix} X & 0 & \dots & 0 \\ 0 & X & \dots & 0 \\ \cdot & \cdot & \cdot & \cdot \\ 0 & 0 & \dots & X \end{bmatrix} \begin{bmatrix} B_1 \\ B_2 \\ \cdot \\ B_n \end{bmatrix} + \begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \cdot \\ \varepsilon_n \end{bmatrix}. \tag{2-107}$$

For the t^{th} observation, the $n \times n$ covariance matrix of the disturbances is

$$\Omega = \begin{bmatrix} \sigma_{11} & \sigma_{12} & \dots & \sigma_{1n} \\ \sigma_{21} & \sigma_{22} & \dots & \sigma_{2n} \\ \cdot & \cdot & \cdot & \cdot \\ \sigma_{n1} & \sigma_{n2} & \dots & \sigma_{nn} \end{bmatrix}, \tag{2-108}$$

so, from Equation 2-106, we get

$$V = \Omega \otimes I \tag{2-109}$$

and

$$V^{-1} = \Omega^{-1} \otimes I. \tag{2-110}$$

We find that the GLS estimator is

$$\begin{aligned} \hat{B} &= [X'V^{-1}X]^{-1} X'V^{-1}y \\ \hat{B} &= [X'(\Omega^{-1} \otimes I)X]^{-1} X'(\Omega^{-1} \otimes I)y \\ \hat{B} &= \begin{bmatrix} \sigma_{11}(X'X)^{-1} & \sigma_{12}(X'X)^{-1} & \dots & \sigma_{1n}(X'X)^{-1} \\ \sigma_{21}(X'X)^{-1} & \sigma_{22}(X'X)^{-1} & \dots & \sigma_{2n}(X'X)^{-1} \\ \cdot & \cdot & \cdot & \cdot \\ \sigma_{n1}(X'X)^{-1} & \sigma_{n2}(X'X)^{-1} & \dots & \sigma_{nn}(X'X)^{-1} \end{bmatrix} \begin{bmatrix} (X'X)\sum_l \sigma^{1l} b_l \\ (X'X)\sum_l \sigma^{2l} b_l \\ \cdot \\ (X'X)\sum_l \sigma^{nl} b_l \end{bmatrix}, \end{aligned} \tag{2-111}$$

where $l = 1, \dots, n$.

After multiplication, the moment matrices cancel, and we are left with

$$\begin{aligned} \hat{B}_1 &= \Sigma_j\, \sigma_{1j}\, \Sigma_l\, \sigma^{jl}\, b_l, \\ \hat{B}_1 &= b_1(\Sigma_j\, \sigma_{1j}\, \sigma^{j1}) + b_2(\Sigma_j\, \sigma_{1j}\, \sigma^{j2}) + \dots + b_n(\Sigma_j\, \sigma_{1j}\, \sigma^{jn}), \end{aligned} \tag{2-112}$$

where j, and $l = 1, \dots, n$, and

$$b_i = (X'X)^{-1}X'y_i. \tag{2-113}$$

The terms in parentheses in the second line of Equation 2-112 are the elements of the first row of $\Sigma\Sigma^{-1} = I$, so the end result is $\hat{B}_1 = b_1$. Using a similar method, the same results are true for the remaining subvectors, $\hat{B}_i = b_i$. That is, in the Seemingly Unrelated Regressions model, when all equations have the same regressors, the efficient estimator is

single-equation ordinary least squares (OLS is the same as GLS). Also, the asymptotic covariance matrix of $\hat{B}$ is given by the large matrix in brackets above, which would be estimated by

$$\text{Est. Asy. Var}[\hat{B}] = \hat{\Omega} \otimes (X'X)^{-1}, \qquad (2\text{-}114)$$

where

$$\hat{\Omega} = \hat{\sigma}_{ij} = (1/T)\ e_i'e_j, \qquad (2\text{-}115)$$

or

$$\text{Est. Asy. Cov}[\hat{B}_i\ \hat{B}_j] = \hat{\sigma}_{ij}\,(X'X)^{-1}, \qquad (2\text{-}116)$$

where $i, j = 1, \dots, n$.

Barten's Method of Estimation

Following Barten (1969), the Maximum Likelihood (ML) method has been used to estimate the coefficients of the demand systems. Maximum-likelihood estimators are consistent, asymptotically efficient, and asymptotically normally distributed. The disadvantages in using the ML procedure are the possible small-sample bias of the estimator for the variances and covariances, the need to specify a distribution for the random variables in the model, and the procedure's computational difficulties. The likelihood function is to be maximized with respect to the coefficient of the system and the elements of the covariance matrix Σ_n. Derivation of the ML estimators will be done in terms of maximizing the concentrated version of the logarithmic-likelihood function,

$$\ln L = 1/2\,(T \ln n - T(n-1)\,(1 + \ln 2\pi) - T \ln|A|), \qquad (2\text{-}117)$$

where

$$A = (1\,/\,T)\,\Sigma_t\, v_t v_t' \qquad (2\text{-}118)$$

and

$$v_t = y_t - Dx_t. \tag{2-119}$$

An alternative way of writing v_t is

$$V = Y - XD', \tag{2-120}$$

where

$$V' = [v_1, v_2, \ldots, v_T], \tag{2-121}$$

$$X' = [x_1, x_2, \ldots, x_T], \tag{2-122}$$

$$Y' = [y_1, y_2, \ldots, y_T]. \tag{2-123}$$

Then

$$A = (1 / T)\, V'V + ii'$$
$$A = (1/T)\, [Y'Y - DX'Y - Y'XD' + DX'XD'] + ii', \tag{2-124}$$

where

$$i = (1 / \sqrt{n})\,\iota \tag{2-125}$$

and ι is the summation vector.

The resulting estimators of the coefficients of the system are used to obtain an estimator of variance, and hence a numerical estimate for the covariance of the disturbances, Ω. The set of equations will be estimated jointly by using a maximum likelihood procedure (Barten, 1969). First, we estimate without the use of any restriction, next we impose a constraint for homogeneity condition, and then we impose constraints for both homogeneity and symmetry conditions. The assumption is made that prices and total expenditure are stochastic and independent of the disturbance term. We also assumed that v_t are vectors of independent random drawings from a multivariate-normal distribution with mean zero and covariance matrix, Ω.

Unconstrained estimation

Starting from an unconstrained estimation, the estimator of h_i and h_{ij} will be derived, which corresponds with the maximum of the concentrated likelihood function without the use of any restriction. For the first-order conditions for a maximum of the concentrated likelihood function with respect to the elements of D,

$$\partial(\ln L) / \partial D = \partial\,[1/2\,(T \ln n - T(n-1)(1 + \ln 2\pi) - T \ln|A|)] / \partial D,$$
$$\partial(\ln L) / \partial D = -(1/2)\partial\,(T \ln |A|) / \partial D,$$
$$\partial(\ln L) / \partial D = -(1/2)A^{-1}[\partial(TA) / \partial D],$$

from $\partial(\ln f(x)) / \partial x = f^{-1}(x)\,[\partial f(x) / \partial x]$,

$$\partial(\ln L) / \partial D = -(1/2)A^{-1}\{\partial[T(1/T)\,(Y'Y - DX'Y - Y'XD' + DX'XD')] / \partial D\},$$

from $\partial(ax') / \partial x = a$, If $xa = (xa)'$, then $\partial(xa) / \partial x = \partial(xa)' / \partial x = \partial(a'x') / \partial x = a'$,

and $\partial(x'ax) / \partial x = ax + (x'a)' = ax + a'x$ ($\partial(x'ax) / \partial x = 2ax$, if $a = a'$), then

$$\partial(\ln L) / \partial D = (1/2)A^{-1}\,[2Y'X - 2D_1X'X],$$
$$\partial(\ln L) / \partial D = A^{-1}\,[Y'X - D_1X'X]. \qquad (2\text{-}126)$$

From $\partial \ln L / \partial D = 0$ and $A^{-1} \neq 0$, we can solve for D_1,

$$Y'X - D_1X'X = 0,$$
$$D_1\,(X'X)^{-1} = Y'X,$$
$$D_1 = Y'X(X'X)^{-1},$$
$$D_1' = (X'X)^{-1}X'Y, \qquad (2\text{-}127)$$

where D_1 is the unconstrained ML estimator. The covariance matrix of this estimator is

$$E[(d^1 - d)(d^1 - d)'] = \Omega \otimes (X'X)^{-1}, \qquad (2\text{-}128)$$

where d^1 is an $n(n+2)$ component vector by arranging the n columns of D_1'. It is obvious that this is simply the ordinary least squares (OLS) estimator applied to each equation separately.

Estimation under the homogeneity condition

The homogeneity condition states that $\Sigma_j h_{ij} = 0$. This can also be formulated in terms of D as

$$D\tau = 0, \tag{2-129}$$

where τ is defined by

$$\tau' = [0, 1, 1, \ldots, 1]_{1 \times (n+1)}. \tag{2-130}$$

The Lagrangean expression with the homogeneity condition is

$$\mathscr{L} = \ln L + \kappa' D\tau, \tag{2-131}$$

where κ is an n-element vector of Lagrangean multipliers. By differentiating this Lagrangean expression with respect to the element of D,

$$\partial(\ln L + \kappa' D\tau) / \partial D = \partial(\ln L) / \partial D + \kappa'(D\tau) / \partial D,$$

from $\partial(a'xb) / \partial x = ab'$ and $\partial(\ln L) / \partial D = A^{-1} [Y'X - DX'X]$, then

$$\partial(\ln L + \kappa' D\tau) / \partial D = A^{-1} [Y'X - D_2X'X] + \kappa\tau'.$$

By pre-multiplying this expression by A, post-multiplying it by $(X'X)^{-1}$, and then using $D_1 = Y'X(X'X)^{-1}$, we obtain

$$\begin{aligned} \partial(\ln L + \kappa' D\tau) / \partial D &= AA^{-1} [Y'X - D_2X'X] (X'X)^{-1} + A\kappa\tau'(X'X)^{-1} \\ \partial(\ln L + \kappa' D\tau) / \partial D &= Y'X(X'X)^{-1} - D_2 + A\kappa\tau' (X'X)^{-1} \\ \partial(\ln L + \kappa' D\tau) / \partial D &= D_1 - D_2 + A\kappa\tau' (X'X)^{-1}. \end{aligned} \tag{2-132}$$

Since D_2 is the ML estimator under the homogeneity condition, it has to satisfy $D_2\tau = 0$. Post-multiplying Equation 2-132 by τ, we get

$$\begin{aligned} &D_1\tau - D_2\tau + A\kappa\tau' (X'X)^{-1}\tau = 0 \\ &A\kappa = - D_1\tau / [\tau' (X'X)^{-1}\tau] \\ &A\kappa = - \theta D_1\tau, \end{aligned} \tag{2-133}$$

where θ is a scalar equaling $1 / \tau' (X'X)^{-1}\tau$. Then we get

$$D_1 - D_2 - \theta D_1 \tau\tau' (X'X)^{-1} = 0$$
$$D_2' = [I - \theta (X'X)^{-1} \tau\tau'] D_1'$$
$$D_2' = [I - \theta (X'X)^{-1} \tau\tau'] [(X'X)^{-1} X'Y]$$
$$D_2' = [(X'X)^{-1} - \theta (X'X)^{-1} \tau\tau' (X'X)^{-1}] X'Y$$
$$D_2' = GX'Y, \tag{2-134}$$

where

$$G = [(X'X)^{-1} - \theta (X'X)^{-1} \tau\tau' (X'X)^{-1}] \tag{2-135}$$

and

$$\tau' G = 0. \tag{2-136}$$

The complete covariance matrix of the ML estimator under the homogeneity condition is

$$E[(d^2 - d)(d^2 - d)'] = \Omega \otimes G, \tag{2-137}$$

where d^2 is a $n(n+2)$ component vector by arranging the n columns of D_2'.

Estimation under the symmetry and homogeneity conditions

The symmetry condition, $h_{ij} = h_{ji}$, can also be formulated in terms of d by

$$r'd = h_{ij} - h_{ji} = 0, \tag{2-138}$$

where d, the $n(n + 2)$ component vector, is formally defined by

$$(I \otimes D')e = d, \tag{2-139}$$

with e being an n^2 component vector of the following structure,

$$e' = [e_1', e_2', \ldots, e_n'], \tag{2-140}$$

and r is a row vector with one in the $[(i - 1)(n + 1) + j + 1]^{th}$ position minus one in the $[(j - 1)(n + 1) + i + 1]^{th}$ position, and otherwise consisting of zeros. There are $0.5n(n - 1)$ different symmetry conditions. These will be represented by

$$Rd = 0, \tag{2-141}$$

where R is a matrix of $0.5n(n - 1)$ rows and $n(n + 2)$ columns. The homogeneity condition can also be formulated in terms of d by

$$[I \otimes \tau' D']e = [I \otimes \tau'] \, [I \otimes D']e = [I \otimes \tau']d = 0. \tag{2-142}$$

The Lagrangean expression to be maximized under the homogeneity and symmetry condition is

$$\mathscr{L} = ln\, L + \kappa'[I \otimes \tau']d + \mu' Rd, \tag{2-143}$$

where κ is a vector of n Lagrange multipliers for the homogeneity condition, and μ is a vector of $0.5n(n-1)$ Lagrange multipliers for the symmetry condition. The vector of first-order derivatives of $ln\, L$ with respect to d can be written as

$$\begin{aligned} \partial(ln\, L) / \partial d &= I \otimes (\partial\, ln\, L / \partial D'), \\ \partial(ln\, L) / \partial d &= [I \otimes (X'Y - X'XD_3')\, A^{-1}]e, \\ \partial(ln\, L) / \partial d &= [A^{-1} \otimes (X'Y - X'XD_3')]e, \end{aligned} \tag{2-144}$$

and from $\partial\, ax / \partial x = a'$ then

$$\begin{aligned} \partial\kappa'[I \otimes \tau']d / \partial d &= \partial[\kappa' \otimes \tau']d / \partial d, \\ \partial\kappa'[I \otimes \tau']d / \partial d &= [\kappa' \otimes \tau']', \\ \partial\kappa'[I \otimes \tau']d / \partial d &= [\kappa \otimes \tau], \end{aligned} \tag{2-145}$$

and

$$\partial\, \mu' Rd / \partial d = (\mu' R)' = R'\mu. \tag{2-146}$$

The first-order condition with respect to d of the Lagrangean expression with the homogeneity and symmetry conditions, Equation 2-143, is

$$[A^{-1} \otimes (X'Y - X'XD_3')]e + [\kappa \otimes \tau] + R'\mu = 0. \tag{2-147}$$

Since it is required that $\tau' D_3' = 0$ in view of the homogeneity condition, and we know that $D_2' = GX'Y$ and $\tau' G = 0$, by pre-multiplying Equation 2-143 by $[A \otimes G]$, we get

$$\begin{aligned} &[A \otimes G]\, [A^{-1} \otimes (X'Y - X'XD_3')]e + [A \otimes G]\, [\kappa \otimes \tau] + [A \otimes G]R'\mu = 0 \\ &[I \otimes (GX'Y - GX'XD_3')]e + [A\kappa \otimes G\tau] + [A \otimes G]R'\mu = 0 \\ &[I \otimes (D_2' - [I - \theta(X'X)^{-1}\, \tau\tau']D_3')]e + [A \otimes G]R'\mu = 0 \\ &[I \otimes (D_2' - D_3')]e + [A \otimes G]R'\mu = 0 \\ &d^2 - d^3 + [A \otimes G]R'\mu = 0. \end{aligned} \tag{2-148}$$

Since $Rd^3 = 0$ meets the symmetry condition. By pre-multiplying Equation 2-148 by R, we get

$$Rd^2 - Rd^3 + R[A \otimes G]R'\mu = 0$$
$$\mu = -[R(A \otimes G)R']^{-1}R(d^2 - d^3)$$
$$\mu = -[R(A \otimes G)R']^{-1}Rd^2. \tag{2-149}$$

From Equation 2-148 and Equation 2-149, we get

$$d^3 = d^2 - (A \otimes G)R'[R(A \otimes G)R']^{-1}Rd^2 = Hd^2, \tag{2-150}$$

where

$$H = I - (A \otimes G)R'[R(A \otimes G)R']^{-1}R. \tag{2-151}$$

The covariance matrix of d^3 can be approximated by

$$E[(d^3 - d)(d^3 - d)'] = H(\Omega \otimes G)H'. \tag{2-152}$$

Empirical Results

The results of the estimation with the homogeneity and symmetry conditions (using the mean of the budget share to multiply the logarithmic version of the inverse demand system by following Barten's estimation method for each functional form in each market) are presented in Tables 2-1 through 2-16. Next, the results of the estimation of the homogeneity and symmetry conditions (using the moving average of the budget share to multiply the logarithmic version of inverse demand system by following Barten's estimation for each functional form in each market) are presented in Tables 2-17 through 2-32. The results from the unconstraint estimation for each market are presented in Tables 2-33 through 2-36. The results from the estimation of the RIDS model with the homogeneity condition (by following Barten's estimation method in each market) are presented in Tables 2-37 through 2-40. The elasticities calculated from the coefficients of the inverse demand system for each market are presented in Tables 2-41 through 2-44.

Inverse Demand System Analysis

The results from the estimation of the inverse demand system in every market (Tables 2-1 through 2-16) show that by using the mean of the budget share to multiply the logarithmic version of the inverse demand system, the RIDS has the same scale coefficients as the RAIIDS model, and the AIIDS model has the same scale coefficients as the La-Theil model. The quantity coefficients are the same between the RIDS model and the La-Theil model, and are the same between the AIIDS model and the RAIIDS model. The scale elasticity, quantity elasticity, and standard errors are unchanged across all four functional forms of the inverse demand system.

The results from the estimation using the moving average of the budget share (Tables 2-17 through 2-32) show that the coefficients are different from the estimation using the mean of the budget share. We also can see that by using the moving average, a different functional form generates a different result.

The results from the unconstrained estimation (Tables 2-33 through 2-36) show that the relative size of the estimated asymptotic standard errors is so large that not too much value can be attached to these results. Therefore, the unconstrained estimation results in imprecise point estimates. Moreover, the results of the estimation with the homogeneity constraint imposed (Tables 2-37 through 2-40) show that the homogeneity condition on it own cannot contribute much to the precision of the estimator. Though we could have expected smaller values for the standard errors, because of the use of a more restrictive model, this hope is almost not realized. In this respect much more can be expected from using the symmetry condition.

Elasticity Analysis

We calculated the elasticities for each market from the estimation of the RIDS model by using Barten's method of estimation with homogeneity and symmetry constraints imposed (Tables 2-1, 2-5, 2-9, and 2-13). The results from Tables 2-41 through 2-44 show that all elasticities in every market have the correct sign according to theory. Tomato has the highest absolute value of the own substitution elasticity when compared with other commodities for every market. In contrast, strawberry has the lowest absolute value of the own substitution elasticity when compared with other commodities for every market. The elasticities for the inverse demand system are closer between the Atlanta and Los Angeles markets and between the Chicago and New York markets.

Scale effect and scale elasticity

Scale effects show how much the normalized price of good *i* will change in response to a proportional increase in the total quantity in all commodities. This reflects the change in total expenditure. It denotes the change in utility, and addresses the question of how prices change as you increase the scale of the commodity vector along a ray radiating from the origin through a commodity vector. It measures the change in the Divisia quantity index, showing the movement from one indifference curve to another. Scale effects are converted into scale elasticities by dividing the scale effects by the budget share. The scale elasticities are considered analogous to the total expenditure (income) elasticities in the direct demand system. All the estimates for the scale effects are statistically significant at the 5% probability level and have the expected sign.

Tomatoes. The obtained estimates for the scale effects of tomatoes in the Atlanta, Los Angeles, Chicago, and New York markets are -0.5427, -0.5224, -0.4488, and -0.4577,

respectively. This showed that for a 1% increase in aggregate quantity in each market, the wholesale price of tomatoes will fall between 0.4488% and 0.5427%. The scale elasticities are -0.9617, -0.9075, -1.0259, and -1.0453 in the Atlanta, Los Angeles, Chicago, and New York markets, respectively (almost unit elastic in the Atlanta market, with the highest fluctuations in the New York market).

Bell peppers. The estimates of the scale effects of bell peppers had the expected negative sign (which showed that as aggregate quantity increases, the normalized price goes down). Since it is expected that the change in normalized price is proportional for both wholesale and retail prices, the magnitude of the above change would be reflected at both the wholesale and retail levels. As such, the obtained estimates of the scale effects can be used to infer that if there is a 1% increase in the quantity of the product group as a whole, the price of bell pepper will fall by 0.1777%, 0.1885%, 0.2226%, and 0.1968% in the Atlanta, Los Angeles, Chicago, and New York markets, respectively. The scale elasticities range from -1.0040 to -1.0905, which are elastic in the Atlanta, Los Angeles and Chicago markets with the scale elasticities equal to -1.0460, -1.0302, and -1.0905, respectively (almost unit elastic in the New York market, with the scale elasticity equal to -1.0040).

Cucumbers. The estimates show that for a 1% increase in the aggregate quantity in each market, the normalized wholesale prices will decrease by 0.1911%, 0.1517%, 0.2319%, and 0.2388% in the Atlanta, Los Angeles, Chicago, and New York markets, respectively. The scale elasticities of cucumbers are -1.0485, -1.0365, -0.892, and -0.9438 in the Atlanta, Los Angeles, Chicago, and New York markets, respectively (inelastic in the Chicago and New York markets and elastic in the Atlanta and Los Angeles markets).

Strawberries. The obtained estimates for the scale effects of strawberries in the Atlanta, Los Angeles, Chicago, and New York markets are -0.0963, -0.1157, -0.0805, and -0.1120, respectively. This showed that for a 1% increase in aggregate quantity, the price for strawberries will decrease by 0.0963%, 0.1157%, 0.0805%, and 0.1120% for the Atlanta, Los Angeles, Chicago, and New York markets, respectively. The scale elasticities of strawberries are -1.1526, -1.2194, -0.8188, and -0.9910 in the Atlanta, Los Angeles, Chicago, and New York markets, respectively (elastic in the Atlanta and Los Angeles markets, elastic in the Chicago market, and almost unit elastic in the New York market).

Quantity effect and own substitution quantity elasticity

Quantity effects represent the compensated or substitution effects of quantity change. These effects show movement along a given indifference surface. These are converted into quantity elasticities by dividing the quantity effects by the budget share. The quantity elasticities are analogous to the price elasticities in the direct demand. They reflect how much the price of good *i* must change to induce the consumer to absorb more of good *j*. The uncompensated quantity elasticities can be calculated by using the Antonelli equation (Equation2-92). In an inverse demand system, a negative quantity effect denotes substitution and a positive quantity denotes complimentarily (the reverse of the direct demand system). The obtained estimates of the own substitution effects have the expected sign, and are statistically significant at the 5% probability level for all commodities in the Atlanta, Los Angeles and New York markets. In the Chicago market, it is statistically significant only for the own substitution effect of strawberries.

In terns of the quantity effects, in the Atlanta market, the estimate combinations of tomato and cucumber and of tomato and bell pepper are statistically significant at the 5%

probability level. In the Los Angeles market, the estimate combination of tomato and cucumber, the estimate combinations of tomato and bell pepper, and of tomato and strawberry are statistically significant at the 5% probability level. In the New York market, the estimate combinations of tomato and cucumber, of tomato and strawberry, and of cucumber and bell pepper are statistically significant at the 5% probability level. In the Chicago market, the estimate combination of cucumber and strawberry is statistically significant at the 5% probability level.

Tomatoes. The obtained estimates for the own substitution quantity effects of tomatoes in the Atlanta, Los Angeles, Chicago, and New York markets are -0.0763, -0.1124, -0.0220, and -0.0245, respectively. The compensated own substitution quantity elasticities of tomatoes in the Atlanta, Los Angeles, Chicago, and New York markets are -0.1352, -0.1953, -0.0502, -0.0560, respectively. The uncompensated own substitution quantity elasticities of tomatoes in the Atlanta, Los Angeles, Chicago, and New York markets are -0.6778, -0.7178, -0.4990, -0.5138, respectively.

Bell peppers. The obtained estimates for the own substitution quantity effects of bell peppers in the Atlanta, Los Angeles, Chicago, and New York markets are -0.0412, -0.0382, -0.0192, and -0.0284, respectively. The compensated own substitution quantity elasticities of bell peppers in the Atlanta, Los Angeles, Chicago, and New York markets are -0.2426, -0.2086, -0.0938, -0.1447, respectively. The uncompensated own substitution quantity elasticities of bell peppers in the Atlanta, Los Angeles, Chicago, and New York markets are -0.4204, -0.3971, -0.3165, -0.3416, respectively.

Cucumbers. The obtained estimates for the own substitution quantity effects of cucumbers in the Atlanta, Los Angeles, Chicago, and New York markets are -0.0320,

-0.0366, -0.0189, and -0.0432, respectively. The compensated own substitution quantity elasticities of cucumbers in the Atlanta, Los Angeles, Chicago, and New York markets are -0.1754, -0.2500, -0.0726, -0.1709, respectively. The uncompensated own substitution quantity elasticities of cucumbers in the Atlanta, Los Angeles, Chicago, and New York markets are -0.3665, -0.4018, -0.3045, -0.4097, respectively.

Strawberries. The obtained estimates for the own substitution quantity effects of strawberries in the Atlanta, Los Angeles, Chicago, and New York markets are -0.0111, -0.0182, -0.0186, and -0.0164, respectively. The compensated own substitution quantity elasticities of strawberries in the Atlanta, Los Angeles, Chicago, and New York markets are -0.1328, -0.1915, -0.1896, -0.1451, respectively. The uncompensated own substitution quantity elasticities of strawberries in the Atlanta, Los Angeles, Chicago, and New York markets are -0.2291, -0.3073, -0.2701, -0.2571, respectively.

Conclusions

To get the demand system that satisfies the neoclassical restrictions, we multiply the budget share by the logarithmic of the demand system. On the empirical estimation, it is better to use the mean of the budget share, $\overline{w}_i$, instead of the moving average of the budget share, w^*_{it}, to multiply the logarithmic of the demand system. The results show the significant effect by using the mean of the budget share on every functional form of both direct and inverse demand systems. Moreover, by using the mean of the budget share, we can obviate the need to choose among various functional forms. The results also show that the estimation of the elasticity and the disturbance of the demand system are the same across all functional forms of the inverse demand system. Overall, it is better to use the RIDS model for fruits and vegetables to avoid statistical inconsistencies

(as the right-hand side variables in the systems should not be controlled by the decision maker) and to avoid the problem with the statistical significant test of the coefficients.

The elasticities were calculated from the estimation of the RIDS model by using Barten's method of estimation with homogeneity and symmetry constraints imposed. All the estimations of scale effects are statistically significant at the 5% probability level and have the expected sign. In terms of own substitution quantity effects, these estimations have the expected sign, and are statistically significant at the 5% probability level for all commodities in the Atlanta, Los Angeles, and New York markets. In the Chicago market, the estimation is statistically significant only for strawberry. In every market, tomato has the highest absolute value of own uncompensated quantity elasticity while strawberry has the lowest. In addition, own substitution quantity elasticities for tomato and bell pepper in the Atlanta and Los Angeles markets are higher than in the Chicago and New York markets.

Table 2-1. Estimation of the RIDS model for the Atlanta market by using the mean of the budget share

Parameter	Tomato	Bell Pepper	Cucumber	Strawberry
h	-0.5427	-0.1777	-0.1911	-0.0963
	(0.0287)	(0.0180)	(0.0171)	(0.0106)
h_{Tomato}	-0.0763			
	(0.0181)			
$h_{\text{Bell Pepper}}$	0.0475	-0.0412		
	(0.0107)	(0.0104)		
h_{Cucumber}	0.0254	-0.0037	-0.0320	
	(0.0107)	(0.0075)	(0.0100)	
$h_{\text{Strawberry}}$	0.0033	-0.0025	0.0103	-0.0111
	(0.0064)	(0.0049)	(0.0049)	(0.0047)
Standard Error (σ)	0.0600	0.0379	0.0358	0.0221
R^2	0.7022	0.3433	0.3840	0.3225

Note: Asymptotic standard error of each estimated parameter is shown in parentheses.

Table 2-2. Estimation of the AIIDS model for the Atlanta market by using the mean of the budget share

Parameter	Tomato	Bell Pepper	Cucumber	Strawberry
b	0.0216	-0.0078	-0.0088	-0.0127
	(0.0287)	(0.0180)	(0.0171)	(0.0106)
γ_{Tomato}	0.1696			
	(0.0181)			
$\gamma_{\text{Bell Pepper}}$	-0.0484	0.0998		
	(0.0107)	(0.0104)		
γ_{Cucumber}	-0.0774	-0.0347	0.1171	
	(0.0107)	(0.0075)	(0.0100)	
$\gamma_{\text{Strawberry}}$	-0.0438	-0.0167	-0.0050	0.0655
	(0.0064)	(0.0049)	(0.0049)	(0.0047)
Standard Error (σ)	0.0600	0.0379	0.0358	0.0221
R^2	0.3080	0.3304	0.3877	0.4842

Note: Asymptotic standard error of each estimated parameter is shown in parentheses.

Table 2-3. Estimation of the La-Theil model for the Atlanta market by using the mean of the budget share

Parameter	Tomato	Bell Pepper	Cucumber	Strawberry
b	0.0216	-0.0078	-0.0088	-0.0127
	(0.0287)	(0.0180)	(0.0171)	(0.0106)
h_{Tomato}	-0.0763			
	(0.0181)			
$h_{\text{Bell Pepper}}$	0.0475	-0.0412		
	(0.0107)	(0.0104)		
h_{Cucumber}	0.0254	-0.0037	-0.0320	
	(0.0107)	(0.0075)	(0.0100)	
$h_{\text{Strawberry}}$	0.0033	-0.0025	0.0103	-0.0111
	(0.0064)	(0.0049)	(0.0049)	(0.0047)
Standard Error (σ)	0.0600	0.0379	0.0358	0.0221
R^2	0.0616	0.1278	0.0253	0.0488

Note: Asymptotic standard error of each estimated parameter is shown in parentheses.

Table 2-4. Estimation of the RAIIDS model for the Atlanta market by using the mean of the budget share

Parameter	Tomato	Bell Pepper	Cucumber	Strawberry
h	-0.5427	-0.1777	-0.1911	-0.0963
	(0.0287)	(0.0180)	(0.0171)	(0.0106)
γ_{Tomato}	0.1696			
	(0.0181)			
$\gamma_{\text{Bell Pepper}}$	-0.0484	0.0998		
	(0.0107)	(0.0104)		
γ_{Cucumber}	-0.0774	-0.0347	0.1171	
	(0.0107)	(0.0075)	(0.0100)	
$\gamma_{\text{Strawberry}}$	-0.0438	-0.0167	-0.0050	0.0655
	(0.0064)	(0.0049)	(0.0049)	(0.0047)
Standard Error (σ)	0.0600	0.0379	0.0358	0.0221
R^2	0.6284	0.5406	0.6141	0.6190

Note: Asymptotic standard error of each estimated parameter is shown in parentheses.

Table 2-5. Estimation of the RIDS model for the Los Angeles market by using the mean of the budget share

Parameter	Tomato	Bell Pepper	Cucumber	Strawberry
h	-0.5224	-0.1885	-0.1517	-0.1157
	(0.0306)	(0.0211)	(0.0189)	(0.0128)
h_{Tomato}	-0.1124			
	(0.0209)			
$h_{\text{Bell Pepper}}$	0.0348	-0.0382		
	(0.0133)	(0.0144)		
h_{Cucumber}	0.0500	-0.0003	-0.0366	
	(0.0118)	(0.0100)	(0.0120)	
$h_{\text{Strawberry}}$	0.0276	0.0037	-0.0131	-0.0182
	(0.0083)	(0.0073)	(0.0065)	(0.0071)
Standard Error (σ)	0.0682	0.0479	0.0425	0.0289
R^2	0.7011	0.2894	0.2223	0.2804

Note: Asymptotic standard error of each estimated parameter is shown in parentheses.

Table 2-6. Estimation of the AIIDS model for the Los Angeles market by using the mean of the budget share

Parameter	Tomato	Bell Pepper	Cucumber	Strawberry
b	0.0533	-0.0055	-0.0053	-0.0208
	(0.0306)	(0.0211)	(0.0189)	(0.0128)
γ_{Tomato}	0.1318			
	(0.0209)			
$\gamma_{\text{Bell Pepper}}$	-0.0706	0.1113		
	(0.0133)	(0.0144)		
γ_{Cucumber}	-0.0342	-0.0271	0.0884	
	(0.0118)	(0.0100)	(0.0120)	
$\gamma_{\text{Strawberry}}$	-0.0270	-0.0137	-0.0270	0.0677
	(0.0083)	(0.0073)	(0.0065)	(0.0071)
Standard Error (σ)	0.0682	0.0479	0.0425	0.0289
R^2	0.2349	0.2186	0.1830	0.3226

Note: Asymptotic standard error of each estimated parameter is shown in parentheses.

Table 2-7. Estimation of the La-Theil model for the Los Angeles market by using the mean of the budget share

Parameter	Tomato	Bell Pepper	Cucumber	Strawberry
b	0.0533	-0.0055	-0.0053	-0.0208
	(0.0306)	(0.0211)	(0.0189)	(0.0128)
h_{Tomato}	-0.1124			
	(0.0209)			
$h_{\text{Bell Pepper}}$	0.0348	-0.0382		
	(0.0133)	(0.0144)		
h_{Cucumber}	0.0500	-0.0003	-0.0366	
	(0.0118)	(0.0100)	(0.0120)	
$h_{\text{Strawberry}}$	0.0276	0.0037	-0.0131	-0.0182
	(0.0083)	(0.0073)	(0.0065)	(0.0071)
Standard Error (σ)	0.0682	0.0479	0.0425	0.0289
R^2	0.1338	0.0441	0.0657	0.0552

Note: Asymptotic standard error of each estimated parameter is shown in parentheses.

Table 2-8. Estimation of the RAIIDS model for the Los Angeles market by using the mean of the budget share

Parameter	Tomato	Bell Pepper	Cucumber	Strawberry
h	-0.5224	-0.1885	-0.1517	-0.1157
	(0.0306)	(0.0211)	(0.0189)	(0.0128)
γ_{Tomato}	0.1318			
	(0.0209)			
$\gamma_{\text{Bell Pepper}}$	-0.0706	0.1113		
	(0.0133)	(0.0144)		
γ_{Cucumber}	-0.0342	-0.0271	0.0884	
	(0.0118)	(0.0100)	(0.0120)	
$\gamma_{\text{Strawberry}}$	-0.0270	-0.0137	-0.0270	0.0677
	(0.0083)	(0.0073)	(0.0065)	(0.0071)
Standard Error (σ)	0.0682	0.0479	0.0425	0.0289
R^2	0.5879	0.4712	0.4171	0.5113

Note: Asymptotic standard error of each estimated parameter is shown in parentheses.

Table 2-9. Estimation of the RIDS model for the Chicago market by using the mean of the budget share

Parameter	Tomato	Bell Pepper	Cucumber	Strawberry
h	-0.4488	-0.2226	-0.2319	-0.0805
	(0.0246)	(0.0189)	(0.0189)	(0.0118)
h_{Tomato}	-0.0220			
	(0.0142)			
$h_{\text{Bell Pepper}}$	0.0125	-0.0192		
	(0.0095)	(0.0105)		
h_{Cucumber}	-0.0006	0.0088	-0.0189	
	(0.0098)	(0.0081)	(0.0110)	
$h_{\text{Strawberry}}$	0.0101	-0.0021	0.0107	-0.0186
	(0.0061)	(0.0052)	(0.0053)	(0.0052)
Standard Error (σ)	0.0668	0.0515	0.0515	0.0317
R^2	0.6287	0.4029	0.4386	0.1982

Note: Asymptotic standard error of each estimated parameter is shown in parentheses.

Table 2-10. Estimation of the AIIDS model for the Chicago market by using the mean of the budget share

Parameter	Tomato	Bell Pepper	Cucumber	Strawberry
b	-0.0113	-0.0185	0.0281	0.0178
	(0.0246)	(0.0189)	(0.0189)	(0.0118)
γ_{Tomato}	0.2241			
	(0.0142)			
$\gamma_{\text{Bell Pepper}}$	-0.0769	0.1433		
	(0.0095)	(0.0105)		
γ_{Cucumber}	-0.1143	-0.0443	0.1735	
	(0.0098)	(0.0081)	(0.0110)	
$\gamma_{\text{Strawberry}}$	-0.0329	-0.0222	-0.0149	0.0700
	(0.0061)	(0.0052)	(0.0053)	(0.0052)
Standard Error (σ)	0.0668	0.0515	0.0515	0.0317
R^2	0.5212	0.4744	0.5653	0.4762

Note: Asymptotic standard error of each estimated parameter is shown in parentheses.

Table 2-11. Estimation of the La-Theil model for the Chicago market by using the mean of the budget share

Parameter	Tomato	Bell Pepper	Cucumber	Strawberry
b	-0.0113	-0.0185	0.0281	0.0178
	(0.0246)	(0.0189)	(0.0189)	(0.0118)
h_{Tomato}	-0.0220			
	(0.0142)			
$h_{\text{Bell Pepper}}$	0.0125	-0.0192		
	(0.0095)	(0.0105)		
h_{Cucumber}	-0.0006	0.0088	-0.0189	
	(0.0098)	(0.0081)	(0.0110)	
$h_{\text{Strawberry}}$	0.0101	-0.0021	0.0107	-0.0186
	(0.0061)	(0.0052)	(0.0053)	(0.0052)
Standard Error (σ)	0.0668	0.0515	0.0515	0.0317
R^2	0.0229	0.0137	0.0163	0.0787

Note: Asymptotic standard error of each estimated parameter is shown in parentheses.

Table 2-12. Estimation of the RAIIDS model for the Chicago market by using the mean of the budget share

Parameter	Tomato	Bell Pepper	Cucumber	Strawberry
h	-0.4488	-0.2226	-0.2319	-0.0805
	(0.0246)	(0.0189)	(0.0189)	(0.0118)
γ_{Tomato}	0.2241			
	(0.0142)			
$\gamma_{\text{Bell Pepper}}$	-0.0769	0.1433		
	(0.0095)	(0.0105)		
γ_{Cucumber}	-0.1143	-0.0443	0.1735	
	(0.0098)	(0.0081)	(0.0110)	
$\gamma_{\text{Strawberry}}$	-0.0329	-0.0222	-0.0149	0.0700
	(0.0061)	(0.0052)	(0.0053)	(0.0052)
Standard Error (σ)	0.0668	0.0515	0.0515	0.0317
R^2	0.7224	0.6100	0.6603	0.5739

Note: Asymptotic standard error of each estimated parameter is shown in parentheses.

Table 2-13. Estimation of the RIDS model for the New York market by using the mean of the budget share

Parameter	Tomato	Bell Pepper	Cucumber	Strawberry
h	-0.4577	-0.1968	-0.2388	-0.1120
	(0.0190)	(0.0130)	(0.0159)	(0.0089)
h_{Tomato}	-0.0245			
	(0.0122)			
$h_{\text{Bell Pepper}}$	0.0015	-0.0284		
	(0.0070)	(0.0079)		
h_{Cucumber}	0.0151	0.0232	-0.0432	
	(0.0092)	(0.0067)	(0.0103)	
$h_{\text{Strawberry}}$	0.0079	0.0036	0.0049	-0.0164
	(0.0053)	(0.0045)	(0.0048)	(0.0048)
Standard Error (σ)	0.0785	0.0511	0.0674	0.0364
R^2	0.7956	0.5853	0.5880	0.5370

Note: Asymptotic standard error of each estimated parameter is shown in parentheses.

Table 2-14. Estimation of the AIIDS model for the New York market by using the mean of the budget share

Parameter	Tomato	Bell Pepper	Cucumber	Strawberry
b	-0.0199	-0.0008	0.0142	0.0010
	(0.0190)	(0.0130)	(0.0159)	(0.0089)
γ_{Tomato}	0.2216			
	(0.0122)			
$\gamma_{\text{Bell Pepper}}$	-0.0843	0.1292		
	(0.0070)	(0.0079)		
γ_{Cucumber}	-0.0957	-0.0264	0.1458	
	(0.0092)	(0.0067)	(0.0103)	
$\gamma_{\text{Strawberry}}$	-0.0416	-0.0185	-0.0237	0.0839
	(0.0053)	(0.0045)	(0.0048)	(0.0048)
Standard Error (σ)	0.0785	0.0511	0.0674	0.0364
R^2	0.6571	0.6573	0.4973	0.6015

Note: Asymptotic standard error of each estimated parameter is shown in parentheses.

Table 2-15. Estimation of the La-Theil model for the New York market by using the mean of the budget share

Parameter	Tomato	Bell Pepper	Cucumber	Strawberry
b	-0.0199	-0.0008	0.0142	0.0010
	(0.0190)	(0.0130)	(0.0159)	(0.0089)
h_{Tomato}	-0.0245			
	(0.0122)			
$h_{\text{Bell Pepper}}$	0.0015	-0.0284		
	(0.0070)	(0.0079)		
h_{Cucumber}	0.0151	0.0232	-0.0432	
	(0.0092)	(0.0067)	(0.0103)	
$h_{\text{Strawberry}}$	0.0079	0.0036	0.0049	-0.0164
	(0.0053)	(0.0045)	(0.0048)	(0.0048)
Standard Error (σ)	0.0785	0.0511	0.0674	0.0364
R^2	0.0334	0.0563	0.0946	0.0589

Note: Asymptotic standard error of each estimated parameter is shown in parentheses.

Table 2-16. Estimation of the RAIIDS model for the New York market by using the mean of the budget share

Parameter	Tomato	Bell Pepper	Cucumber	Strawberry
h	-0.4577	-0.1968	-0.2388	-0.1120
	(0.0190)	(0.0130)	(0.0159)	(0.0089)
γ_{Tomato}	0.2216			
	(0.0122)			
$\gamma_{\text{Bell Pepper}}$	-0.0843	0.1292		
	(0.0070)	(0.0079)		
γ_{Cucumber}	-0.0957	-0.0264	0.1458	
	(0.0092)	(0.0067)	(0.0103)	
$\gamma_{\text{Strawberry}}$	-0.0416	-0.0185	-0.0237	0.0839
	(0.0053)	(0.0045)	(0.0048)	(0.0048)
Standard Error (σ)	0.0785	0.0511	0.0674	0.0364
R^2	0.7536	0.8456	0.7560	0.6830

Note: Asymptotic standard error of each estimated parameter is shown in parentheses

Table 2-17. Estimation of the RIDS model for the Atlanta market by using the moving average of the budget share

Parameter	Tomato	Bell Pepper	Cucumber	Strawberry
h	-0.5421	-0.1706	-0.1871	-0.1014
	(0.0276)	(0.0199)	(0.0165)	(0.0116)
h_{Tomato}	-0.0856			
	(0.0179)			
$h_{\text{Bell Pepper}}$	0.0490	-0.0428		
	(0.0112)	(0.0112)		
h_{Cucumber}	0.0291	-0.0009	-0.0372	
	(0.0102)	(0.0077)	(0.0099)	
$h_{\text{Strawberry}}$	0.0075	-0.0053	0.0091	-0.0112
	(0.0069)	(0.0054)	(0.0051)	(0.0052)
Standard Error (σ)	0.0574	0.0422	0.0346	0.0244
R^2	0.7264	0.2814	0.3916	0.2906

Note: Asymptotic standard error of each estimated parameter is shown in parentheses.

Table 2-18. Estimation of the AIIDS model for the Atlanta market by using the moving average of the budget share

Parameter	Tomato	Bell Pepper	Cucumber	Strawberry
b	0.0157	-0.0048	-0.0004	-0.0118
	(0.0277)	(0.0200)	(0.0167)	(0.0124)
γ_{Tomato}	0.1601			
	(0.0180)			
$\gamma_{\text{Bell Pepper}}$	-0.0432	0.0912		
	(0.0112)	(0.0113)		
γ_{Cucumber}	-0.0807	-0.0314	0.1137	
	(0.0103)	(0.0077)	(0.0100)	
$\gamma_{\text{Strawberry}}$	-0.0362	-0.0166	-0.0016	0.0545
	(0.0073)	(0.0057)	(0.0054)	(0.0056)
Standard Error (σ)	0.0577	0.0424	0.0349	0.0260
R^2	0.2907	0.2653	0.3773	0.3170

Note: Asymptotic standard error of each estimated parameter is shown in parentheses.

Table 2-19. Estimation of the La-Theil model for the Atlanta market by using the moving average of the budget share

Parameter	Tomato	Bell Pepper	Cucumber	Strawberry
b	0.0231	-0.0044	-0.0090	-0.0108
	(0.0276)	(0.0200)	(0.0163)	(0.0114)
h_{Tomato}	-0.0765			
	(0.0179)			
$h_{\text{Bell Pepper}}$	0.0472	-0.0397		
	(0.0112)	(0.0112)		
h_{Cucumber}	0.0244	-0.0017	-0.0322	
	(0.0102)	(0.0076)	(0.0097)	
$h_{\text{Strawberry}}$	0.0050	-0.0058	0.0095	-0.0087
	(0.0068)	(0.0054)	(0.0051)	(0.0051)
Standard Error (σ)	0.0574	0.0424	0.0342	0.0240
R^2	0.0758	0.1008	0.0287	0.0301

Note: Asymptotic standard error of each estimated parameter is shown in parentheses.

Table 2-20. Estimation of the RAIIDS model for the Atlanta market by using the moving average of the budget share

Parameter	Tomato	Bell Pepper	Cucumber	Strawberry
h	-0.5493	-0.1709	-0.1786	-0.1024
	(0.0278)	(0.0200)	(0.0171)	(0.0128)
γ_{Tomato}	0.1507			
	(0.0181)			
$\gamma_{\text{Bell Pepper}}$	-0.0415	0.0885		
	(0.0112)	(0.0113)		
γ_{Cucumber}	-0.0756	-0.0308	0.1087	
	(0.0106)	(0.0079)	(0.0104)	
$\gamma_{\text{Strawberry}}$	-0.0336	-0.0161	-0.0022	0.0519
	(0.0075)	(0.0058)	(0.0056)	(0.0058)
Standard Error (σ)	0.0578	0.0423	0.0359	0.0270
R^2	0.6493	0.4549	0.5789	0.4635

Note: Asymptotic standard error of each estimated parameter is shown in parentheses.

Table 2-21. Estimation of the RIDS model for the Los Angeles Market by using the moving average of the budget share

Parameter	Tomato	Bell Pepper	Cucumber	Strawberry
h	-0.5534	-0.1794	-0.1674	-0.1031
	(0.0309)	(0.0208)	(0.0203)	(0.0138)
h_{Tomato}	-0.1184			
	(0.0213)			
$h_{Bell\ Pepper}$	0.0425	-0.0432		
	(0.0133)	(0.0147)		
$h_{Cucumber}$	0.0520	-0.0008	-0.0370	
	(0.0127)	(0.0106)	(0.0134)	
$h_{Strawberry}$	0.0239	0.0015	-0.0141	-0.0113
	(0.0088)	(0.0078)	(0.0072)	(0.0078)
Standard Error (σ)	0.0687	0.0471	0.0456	0.0309
R^2	0.7200	0.2743	0.2378	0.2170

Note: Asymptotic standard error of each estimated parameter is shown in parentheses.

Table 2-22. Estimation of the AIIDS model for the Los Angeles market by using the moving average of the budget share

Parameter	Tomato	Bell Pepper	Cucumber	Strawberry
b	0.0300	-0.0006	-0.0137	-0.0190
	(0.0300)	(0.0208)	(0.0196)	(0.0141)
γ_{Tomato}	0.1279			
	(0.0207)			
$\gamma_{Bell\ Pepper}$	-0.0639	0.1010		
	(0.0133)	(0.0150)		
$\gamma_{Cucumber}$	-0.0353	-0.0255	0.0872	
	(0.0123)	(0.0105)	(0.0129)	
$\gamma_{Strawberry}$	-0.0286	-0.0116	-0.0263	0.0665
	(0.0090)	(0.0080)	(0.0073)	(0.0081)
Standard Error (σ)	0.0668	0.0473	0.0439	0.0317
R^2	0.2123	0.1954	0.1721	0.2682

Note: Asymptotic standard error of each estimated parameter is shown in parentheses.

Table 2-23. Estimation of the La-Theil model for the Los Angeles market by using the moving average of the budget share

Parameter	Tomato	Bell Pepper	Cucumber	Strawberry
b	0.0429	-0.0083	-0.0163	-0.0216
	(0.0297)	(0.0205)	(0.0194)	(0.0133)
h_{Tomato}	-0.1076			
	(0.0204)			
$h_{\text{Bell Pepper}}$	0.0355	-0.0364		
	(0.0131)	(0.0146)		
h_{Cucumber}	0.0480	-0.0011	-0.0314	
	(0.0122)	(0.0103)	(0.0128)	
$h_{\text{Strawberry}}$	0.0241	0.0019	-0.0155	-0.0104
	(0.0085)	(0.0076)	(0.0070)	(0.0076)
Standard Error (σ)	0.0660	0.0465	0.0435	0.0298
R^2	0.1277	0.0435	0.0545	0.0491

Note: Asymptotic standard error of each estimated parameter is shown in parentheses.

Table 2-24. Estimation of the RAIIDS model for the Los Angeles market by using the moving average of the budget share

Parameter	Tomato	Bell Pepper	Cucumber	Strawberry
h	-0.5663	-0.1717	-0.1649	-0.1004
	(0.0315)	(0.0213)	(0.0208)	(0.0148)
γ_{Tomato}	0.1171			
	(0.0217)			
$\gamma_{\text{Bell Pepper}}$	-0.0570	0.0942		
	(0.0136)	(0.0151)		
γ_{Cucumber}	-0.0312	-0.0254	0.0815	
	(0.0130)	(0.0109)	(0.0137)	
$\gamma_{\text{Strawberry}}$	-0.0289	-0.0118	-0.0249	0.0656
	(0.0094)	(0.0083)	(0.0077)	(0.0085)
Standard Error (σ)	0.0701	0.0482	0.0467	0.0332
R^2	0.6159	0.4073	0.3806	0.3984

Note: Asymptotic standard error of each estimated parameter is shown in parentheses.

Table 2-25. Estimation of the RIDS model for the Chicago market by using the moving average of the budget share

Parameter	Tomato	Bell Pepper	Cucumber	Strawberry
h	-0.4441	-0.2316	-0.2487	-0.0758
	(0.0248)	(0.0203)	(0.0209)	(0.0130)
h_{Tomato}	-0.0246			
	(0.0148)			
$h_{\text{Bell Pepper}}$	0.0164	-0.0220		
	(0.0100)	(0.0113)		
h_{Cucumber}	-0.0019	0.0109	-0.0196	
	(0.0105)	(0.0088)	(0.0120)	
$h_{\text{Strawberry}}$	0.0101	-0.0054	0.0107	-0.0154
	(0.0066)	(0.0057)	(0.0059)	(0.0057)
Standard Error (σ)	0.0674	0.0553	0.0568	0.0348
R^2	0.6201	0.3872	0.4250	0.1583

Note: Asymptotic standard error of each estimated parameter is shown in parentheses.

Table 2-26. Estimation of the AIIDS model for the Chicago market by using the moving average of the budget share

Parameter	Tomato	Bell Pepper	Cucumber	Strawberry
b	-0.0221	-0.0224	0.0223	0.0219
	(0.0233)	(0.0196)	(0.0203)	(0.0140)
γ_{Tomato}	0.2188			
	(0.0141)			
$\gamma_{\text{Bell Pepper}}$	-0.0762	0.1421		
	(0.0096)	(0.0110)		
γ_{Cucumber}	-0.1089	-0.0418	0.1685	
	(0.0100)	(0.0086)	(0.0117)	
$\gamma_{\text{Strawberry}}$	-0.0337	-0.0241	-0.0178	0.0756
	(0.0068)	(0.0059)	(0.0061)	(0.0062)
Standard Error (σ)	0.0632	0.0533	0.0552	0.0377
R^2	0.5404	0.4506	0.5111	0.4199

Note: Asymptotic standard error of each estimated parameter is shown in parentheses.

Table 2-27. Estimation of the La-Theil model for the Chicago market by using the moving average of the budget share

Parameter	Tomato	Bell Pepper	Cucumber	Strawberry
b	-0.0210	-0.0217	0.0231	0.0193
	(0.0231)	(0.0198)	(0.0201)	(0.0129)
h_{Tomato}	-0.0234			
	(0.0138)			
$h_{\text{Bell Pepper}}$	0.0143	-0.0215		
	(0.0096)	(0.0111)		
h_{Cucumber}	-0.0014	0.0111	-0.0190	
	(0.0099)	(0.0086)	(0.0116)	
$h_{\text{Strawberry}}$	0.0104	-0.0040	0.0092	-0.0157
	(0.0064)	(0.0057)	(0.0058)	(0.0057)
Standard Error (σ)	0.0627	0.0539	0.0546	0.0345
R^2	0.0267	0.0191	0.0141	0.0630

Note: Asymptotic standard error of each estimated parameter is shown in parentheses.

Table 2-28. Estimation of the RAIIDS model for the Chicago market by using the moving average of the budget share

Parameter	Tomato	Bell Pepper	Cucumber	Strawberry
h	-0.4453	-0.2322	-0.2496	-0.0732
	(0.0250)	(0.0201)	(0.0210)	(0.0143)
γ_{Tomato}	0.2177			
	(0.0151)			
$\gamma_{\text{Bell Pepper}}$	-0.0741	0.1415		
	(0.0100)	(0.0111)		
γ_{Cucumber}	-0.1094	-0.0420	0.1678	
	(0.0105)	(0.0087)	(0.0120)	
$\gamma_{\text{Strawberry}}$	-0.0341	-0.0254	-0.0164	0.0759
	(0.0071)	(0.0060)	(0.0062)	(0.0063)
Standard Error (σ)	0.0679	0.0545	0.0569	0.0383
R^2	0.7096	0.5853	0.6146	0.4957

Note: Asymptotic standard error of each estimated parameter is shown in parentheses.

Table 2-29. Estimation of the RIDS model for the New York market by using the moving average of the budget share

Parameter	Tomato	Bell Pepper	Cucumber	Strawberry
h	-0.4646	-0.2118	-0.2208	-0.1066
	(0.0182)	(0.0135)	(0.0169)	(0.0100)
h_{Tomato}	-0.0294			
	(0.0119)			
$h_{\text{Bell Pepper}}$	-0.0003	-0.0255		
	(0.0072)	(0.0084)		
h_{Cucumber}	0.0177	0.0212	-0.0406	
	(0.0095)	(0.0072)	(0.0113)	
$h_{\text{Strawberry}}$	0.0120	0.0046	0.0017	-0.0184
	(0.0058)	(0.0050)	(0.0054)	(0.0054)
Standard Error (σ)	0.0745	0.0527	0.0720	0.0413
R^2	0.8176	0.6108	0.5146	0.4475

Note: Asymptotic standard error of each estimated parameter is shown in parentheses.

Table 2-30. Estimation of the AIIDS model for the New York market by using the moving average of the budget share

Parameter	Tomato	Bell Pepper	Cucumber	Strawberry
b	-0.0041	-0.0152	0.0230	-0.0076
	(0.0186)	(0.0138)	(0.0165)	(0.0103)
γ_{Tomato}	0.2047			
	(0.0124)			
$\gamma_{\text{Bell Pepper}}$	-0.0772	0.1256		
	(0.0074)	(0.0086)		
γ_{Cucumber}	-0.0879	-0.0234	0.1353	
	(0.0094)	(0.0073)	(0.0110)	
$\gamma_{\text{Strawberry}}$	-0.0396	-0.0251	-0.0241	0.0887
	(0.0060)	(0.0050)	(0.0054)	(0.0055)
Standard Error (σ)	0.0761	0.0545	0.0700	0.0427
R^2	0.6377	0.6319	0.4528	0.5514

Note: Asymptotic standard error of each estimated parameter is shown in parentheses.

Table 2-31. Estimation of the La-Theil model for the New York market by using the moving average of the budget share

Parameter	Tomato	Bell Pepper	Cucumber	Strawberry
b	-0.4646	-0.2118	-0.2208	-0.1066
	(0.0182)	(0.0135)	(0.0169)	(0.0100)
h_{Tomato}	-0.0294			
	(0.0119)			
$h_{Bell\ Pepper}$	-0.0003	-0.0255		
	(0.0072)	(0.0084)		
$h_{Cucumber}$	0.0177	0.0212	-0.0406	
	(0.0095)	(0.0072)	(0.0113)	
$h_{Strawberry}$	0.0120	0.0046	0.0017	-0.0184
	(0.0058)	(0.0050)	(0.0054)	(0.0054)
Standard Error (σ)	0.0728	0.0506	0.0671	0.0386
R^2	0.0414	0.0542	0.0660	0.0584

Note: Asymptotic standard error of each estimated parameter is shown in parentheses.

Table 2-32. Estimation of the RAIIDS model for the New York market by using the moving average of the budget share

Parameter	Tomato	Bell Pepper	Cucumber	Strawberry
h	-0.4568	-0.2273	-0.2080	-0.1117
	(0.0188)	(0.0149)	(0.0178)	(0.0108)
γ_{Tomato}	0.2030			
	(0.0124)			
$\gamma_{Bell\ Pepper}$	-0.0818	0.1268		
	(0.0078)	(0.0093)		
$\gamma_{Cucumber}$	-0.0814	-0.0224	0.1296	
	(0.0098)	(0.0080)	(0.0121)	
$\gamma_{Strawberry}$	-0.0398	-0.0226	-0.0258	0.0882
	(0.0062)	(0.0054)	(0.0058)	(0.0058)
Standard Error (σ)	0.0768	0.0591	0.0758	0.0444
R^2	0.7525	0.8237	0.6596	0.6025

Note: Asymptotic standard error of each estimated parameter is shown in parentheses

Table 2-33. Unconstrained estimation of the RIDS model for the Atlanta market

Parameter	Tomato	Bell Pepper	Cucumber	Strawberry
h	-0.5868	0.0225	-0.2231	-0.0993
	(0.1905)	(0.1209)	(0.1151)	(0.0715)
h_{Tomato}	-0.0548	-0.0576	0.0395	0.0004
	(0.1120)	(0.0710)	(0.0676)	(0.0420)
$h_{\text{Bell Pepper}}$	0.0154	-0.0715	0.0183	0.0006
	(0.0366)	(0.0232)	(0.0221)	(0.0137)
h_{Cucumber}	0.0603	-0.0640	-0.0247	0.0181
	(0.0418)	(0.0265)	(0.0252)	(0.0157)
$h_{\text{Strawberry}}$	0.0299	-0.0251	0.0032	-0.0123
	(0.0194)	(0.0123)	(0.0117)	(0.0073)
Standard Error (σ)	0.0588	0.0373	0.0355	0.0221
R^2	0.7137	0.3648	0.3947	0.3276

Note: Asymptotic standard error of each estimated parameter is shown in parentheses.

Table 2-34. Unconstrained estimation of the RIDS model for the Los Angeles market

Parameter	Tomato	Bell Pepper	Cucumber	Strawberry
h	-0.3980	-0.2997	0.0717	0.0846
	(0.1786)	(0.1262)	(0.1110)	(0.0749)
h_{Tomato}	-0.1874	0.1039	-0.0908	-0.0928
	(0.1079)	(0.0763)	(0.0671)	(0.0452)
$h_{\text{Bell Pepper}}$	-0.0073	-0.0171	-0.0370	-0.0330
	(0.0394)	(0.0279)	(0.0245)	(0.0165)
h_{Cucumber}	0.0632	0.0102	-0.0765	-0.0511
	(0.0370)	(0.0261)	(0.0230)	(0.0155)
$h_{\text{Strawberry}}$	0.0048	0.0172	-0.0245	-0.0342
	(0.0249)	(0.0176)	(0.0154)	(0.0104)
Standard Error (σ)	0.0676	0.0478	0.0420	0.0283
R^2	0.7059	0.2931	0.2409	0.3061

Note: Asymptotic standard error of each estimated parameter is shown in parentheses.

Table 2-35. Unconstrained estimation of the RIDS model for the Chicago market

Parameter	Tomato	Bell Pepper	Cucumber	Strawberry
h	-0.3565	-0.1354	-0.2338	-0.0799
	(0.1251)	(0.0963)	(0.0964)	(0.0118)
h_{Tomato}	-0.0649	-0.0301	0.0018	0.0049
	(0.0541)	(0.0416)	(0.0416)	(0.0071)
$h_{\text{Bell Pepper}}$	-0.0033	-0.0372	0.0111	-0.0047
	(0.0312)	(0.0240)	(0.0240)	(0.0066)
h_{Cucumber}	-0.0291	-0.0137	-0.0176	0.0165
	(0.0344)	(0.0265)	(0.0265)	(0.0068)
$h_{\text{Strawberry}}$	0.0074	-0.0036	0.0035	-0.0167
	(0.0167)	(0.0129)	(0.0129)	(0.0053)
Standard Error (σ)	0.0667	0.0513	0.0514	0.0316
R^2	0.6306	0.4074	0.4404	0.2036

Note: Asymptotic standard error of each estimated parameter is shown in parentheses.

Table 2-36. Unconstrained estimation of the RIDS model for the New York market

Parameter	Tomato	Bell Pepper	Cucumber	Strawberry
h	-0.5173	-0.2015	-0.1055	-0.0943
	(0.0746)	(0.0486)	(0.0632)	(0.0347)
h_{Tomato}	-0.0008	0.0073	-0.0306	0.0016
	(0.0327)	(0.0213)	(0.0277)	(0.0152)
$h_{\text{Bell Pepper}}$	0.0060	-0.0288	0.0026	-0.0044
	(0.0223)	(0.0146)	(0.0189)	(0.0104)
h_{Cucumber}	0.0233	0.0146	-0.0803	0.0006
	(0.0218)	(0.0142)	(0.0185)	(0.0101)
$h_{\text{Strawberry}}$	0.0235	0.0062	-0.0246	-0.0192
	(0.0138)	(0.0090)	(0.0117)	(0.0064)
Standard Error (σ)	0.0782	0.0510	0.0662	0.0363
R^2	0.7972	0.5880	0.6020	0.5386

Note: Asymptotic standard error of each estimated parameter is shown in parentheses.

Table 2-37. Barten's estimation with the homogeneity condition of the RIDS model for the Atlanta market

Parameter	Tomato	Bell Pepper	Cucumber	Strawberry
h	-0.5378	-0.1879	-0.1881	-0.0927
	(0.0283)	(0.0181)	(0.0171)	(0.0106)
h_{Tomato}	-0.0835	0.0658	0.0190	-0.0035
	(0.0185)	(0.0118)	(0.0112)	(0.0069)
$h_{\text{Bell Pepper}}$	0.0069	-0.0350	0.0122	-0.0005
	(0.0164)	(0.0105)	(0.0099)	(0.0061)
h_{Cucumber}	0.0505	-0.0217	-0.0318	0.0168
	(0.0177)	(0.0113)	(0.0107)	(0.0067)
$h_{\text{Strawberry}}$	0.0261	-0.0091	0.0005	-0.0128
	(0.0131)	(0.0084)	(0.0079)	(0.0049)
Standard Error (σ)	0.0588	0.0376	0.0355	0.0221
R^2	0.7136	0.3553	0.3944	0.3275

Note: Asymptotic standard error of each estimated parameter is shown in parentheses.

Table 2-38. Barten's estimation with the homogeneity condition of the RIDS model for the Los Angeles market

Parameter	Tomato	Bell Pepper	Cucumber	Strawberry
h	-0.5184	-0.1912	-0.1456	-0.1159
	(0.0305)	(0.0216)	(0.0191)	(0.0130)
h_{Tomato}	-0.1150	0.0386	0.0399	0.0278
	(0.0209)	(0.0148)	(0.0131)	(0.0089)
$h_{\text{Bell Pepper}}$	0.0146	-0.0369	0.0027	0.0035
	(0.0229)	(0.0162)	(0.0143)	(0.0098)
h_{Cucumber}	0.0840	-0.0085	-0.0390	-0.0165
	(0.0210)	(0.0149)	(0.0132)	(0.0090)
$h_{\text{Strawberry}}$	0.0164	0.0068	-0.0036	-0.0149
	(0.0182)	(0.0129)	(0.0114)	(0.0078)
Standard Error (σ)	0.0677	0.0479	0.0424	0.0289
R^2	0.7052	0.2905	0.2264	0.2813

Note: Asymptotic standard error of each estimated parameter is shown in parentheses.

Table 2-39. Barten's estimation with the homogeneity condition of the RIDS model for the Chicago market

Parameter	Tomato	Bell Pepper	Cucumber	Strawberry
h	-0.4457	-0.2194	-0.2349	-0.0799
	(0.0249)	(0.0192)	(0.0191)	(0.0118)
h_{Tomato}	-0.0271	0.0054	0.0023	0.0049
	(0.0151)	(0.0116)	(0.0116)	(0.0071)
$h_{\text{Bell Pepper}}$	0.0170	-0.0181	0.0114	-0.0047
	(0.0140)	(0.0107)	(0.0107)	(0.0066)
h_{Cucumber}	-0.0064	0.0077	-0.0173	0.0165
	(0.0144)	(0.0111)	(0.0111)	(0.0068)
$h_{\text{Strawberry}}$	0.0165	0.0049	0.0036	-0.0167
	(0.0111)	(0.0086)	(0.0086)	(0.0053)
Standard Error (σ)	0.0668	0.0514	0.0514	0.0321
R^2	0.6296	0.4051	0.4404	0.1752

Note: Asymptotic standard error of each estimated parameter is shown in parentheses.

Table 2-40. Barten's estimation with the homogeneity condition of the RIDS model for the New York market

Parameter	Tomato	Bell Pepper	Cucumber	Strawberry
h	-0.4678	-0.2022	-0.2320	-0.1147
	(0.0204)	(0.0133)	(0.0175)	(0.0095)
h_{Tomato}	-0.0216	0.0075	0.0224	0.0102
	(0.0127)	(0.0083)	(0.0109)	(0.0059)
$h_{\text{Bell Pepper}}$	-0.0067	-0.0286	0.0350	0.0008
	(0.0128)	(0.0083)	(0.0109)	(0.0059)
h_{Cucumber}	0.0109	0.0148	-0.0487	0.0057
	(0.0125)	(0.0081)	(0.0107)	(0.0058)
$h_{\text{Strawberry}}$	0.0173	0.0063	-0.0087	-0.0166
	(0.0104)	(0.0068)	(0.0089)	(0.0049)
Standard Error (σ)	0.0783	0.0510	0.0669	0.0364
R^2	0.7967	0.5880	0.5936	0.5377

Note: Asymptotic standard error of each estimated parameter is shown in parentheses.

Table 2-41. Elasticities for the Atlanta market

Parameter	Tomato	Bell Pepper	Cucumber	Strawberry
ζ	-0.9617	-1.0460	-1.0485	-1.1526
ξ_{Tomato}	-0.1352	0.2795	0.1396	0.0401
$\xi_{Bell\ Pepper}$	0.0842	-0.2426	-0.0205	-0.0302
$\xi_{Cucumber}$	0.0451	-0.0220	-0.1754	0.1229
$\xi_{Strawberry}$	0.0059	-0.0148	0.0563	-0.1328
ψ_{Tomato}	-0.6778	-0.3108	-0.4520	-0.6103
$\psi_{Bell\ Pepper}$	-0.0793	-0.4204	-0.1987	-0.2260
$\psi_{Cucumber}$	-0.1302	-0.2126	-0.3665	-0.0872
$\psi_{Strawberry}$	-0.0744	-0.1022	-0.0313	-0.2291

Note: ζ is scale elasticity, ξ is compensated elasticity, and ψ is uncompensated elasticity.

Table 2-42. Elasticities for the Los Angeles market

Parameter	Tomato	Bell Pepper	Cucumber	Strawberry
ζ	-0.9075	-1.0302	-1.0365	-1.2194
ξ_{Tomato}	-0.1953	0.1901	0.3418	0.2910
$\xi_{Bell\ Pepper}$	0.0604	-0.2086	-0.0021	0.0389
$\xi_{Cucumber}$	0.0869	-0.0017	-0.2500	-0.1384
$\xi_{Strawberry}$	0.0480	0.0202	-0.0897	-0.1915
ψ_{Tomato}	-0.7178	-0.4030	-0.2549	-0.4110
$\psi_{Bell\ Pepper}$	-0.1056	-0.3971	-0.1917	-0.1842
$\psi_{Cucumber}$	-0.0459	-0.1525	-0.4018	-0.3169
$\psi_{Strawberry}$	-0.0382	-0.0776	-0.1881	-0.3073

Note: ζ is scale elasticity, ξ is compensated elasticity, and ψ is uncompensated elasticity.

Table 2-43. Elasticities for the Chicago market

Parameter	Tomato	Bell Pepper	Cucumber	Strawberry
ζ	-1.0259	-1.0905	-0.8920	-0.8188
ξ_{Tomato}	-0.0502	0.0610	-0.0022	0.1026
$\xi_{Bell\ Pepper}$	0.0285	-0.0938	0.0338	-0.0212
$\xi_{Cucumber}$	-0.0013	0.0431	-0.0726	0.1083
$\xi_{Strawberry}$	0.0231	-0.0102	0.0410	-0.1896
ψ_{Tomato}	-0.4990	-0.4161	-0.3925	-0.2556
$\psi_{Bell\ Pepper}$	-0.1810	-0.3165	-0.1483	-0.1884
$\psi_{Cucumber}$	-0.2681	-0.2404	-0.3045	-0.1046
$\psi_{Strawberry}$	-0.0778	-0.1175	-0.0468	-0.2701

Note: ζ is scale elasticity, ξ is compensated elasticity, and ψ is uncompensated elasticity.

Table 2-44. Elasticities for the New York market

Parameter	Tomato	Bell Pepper	Cucumber	Strawberry
ζ	-1.0453	-1.0040	-0.9438	-0.9910
ξ_{Tomato}	-0.0560	0.0079	0.0598	0.0696
$\xi_{Bell\ Pepper}$	0.0035	-0.1447	0.0917	0.0320
$\xi_{Cucumber}$	0.0345	0.1184	-0.1709	0.0435
$\xi_{Strawberry}$	0.0180	0.0185	0.0194	-0.1451
ψ_{Tomato}	-0.5138	-0.4317	-0.3535	-0.3644
$\psi_{Bell\ Pepper}$	-0.2014	-0.3416	-0.0933	-0.1622
$\psi_{Cucumber}$	-0.2300	-0.1357	-0.4097	-0.2072
$\psi_{Strawberry}$	-0.1002	-0.0950	-0.0872	-0.2571

Note: ζ is scale elasticity, ξ is compensated elasticity, and ψ is uncompensated elasticity.

CHAPTER 3
PARTIAL EQUILIBRIUM ANALYSIS ON FRUIT AND VEGETABLE INDUSTRY

This chapter concentrates on the potential impact of two major developments on the U.S. fruit and vegetable industry. The first development is the proposed phasing out of using methyl bromide. Methyl bromide is a critical soil fumigant that has been used in the production of several fresh fruits and vegetables grown in the United States. The U.S. Clean Air Act of 1992 requires that methyl bromide be phased out of use by 2005. The problem is that while significant progress has been made towards developing alternatives to methyl bromide, a suitable alternative has not been identified. The second development is the elimination of all tariff and trade restrictions on exports of fruits and vegetables from Mexico as a result of the implementation of the North American Free Trade Agreement (NAFTA). Under NAFTA, all agricultural tariffs on goods traded between the United States and Mexico will be eliminated by 2008. Some of the tariffs were eliminated in 1994, while others were to be phased out over 5, 10, or 15 years. In addition, negotiations of trade agreements within the World Trade Organization (WTO) or as part of the Free Trade Area of the Americas (FTAA) could significantly affect these tariffs. The elimination of tariffs means that U.S. domestic production of fresh fruits and vegetables is likely to face increased competition from imports.

To assess the impacts of these developments on the U.S. fruit and vegetable industry, it was essential to develop a partial spatial equilibrium model. Following on a model developed by VanSickle et al., I modified and improved that model by simplifying

regional effects and changing the objective function so that the model can simulate all fruits and vegetables at the same time.

Background

Methyl bromide has been a critical soil fumigant in the agricultural production for many years. Methyl bromide is a broad spectrum pesticide that can be used to control pest insects, nematodes, weeds, pathogens, and rodents. Under normal conditions, methyl bromide is a colorless and odorless gas. About 21,000 tons of methyl bromide are used annually in agriculture in the United States and about 72,000 tons are used globally each year. When used as a soil fumigant, methyl bromide gas is injected into the soil at a depth of 12 to 24 inches before a crop is planted. This procedure effectively sterilizes the soil, and kills a majority of soil organisms. In addition, commodities may be treated with methyl bromide as part of a quarantine requirement of an importing country. Some commodities are treated several times during both storage and shipment.

Methyl bromide was assigned a 0.4 ozone-depletion potential (methyl bromide has contributed about 4% to the current ozone depletion and may contribute 5% to 15% to future ozone depletion if it is not phased out). Methyl bromide is 40 times more efficient at destroying the ozone than chlorine (which should be phased out as well). The degradation of the ozone layer leads to higher levels of ultraviolet radiation reaching the Earth's surface, which could reduce crop yields and could cause health problems (e.g., skin cancer, eye damage, and impaired immune systems).

The impact of methyl bromide on ozone depletion led to the development of the Montreal Protocol in 1987. According to the U.S. Environmental Protection Agency (EPA), the Montreal Protocol was designed to help revise methyl bromide phaseout schedules on the basis of periodic scientific and technological assessments. The U.S.

Clean Air Act of 1992, as amended in 1998, requires that methyl bromide be phased out of use on the basis of separate schedules prepared for developed and developing countries who are party to the Montreal Protocol (Table 3-1). The phaseout of methyl bromide use is being implemented by restricting the volume of methyl bromide that can be produced and sold. So far, efforts to phase out methyl bromide have resulted in a 50% reduction in use (the first two 25% reductions have already occurred in the United States). Table 3-1 shows the schedule for phasing out methyl bromide. Developing countries can still use methyl bromide until 2015 (10 years after the phaseout in the developed countries). There is concern that developed countries could be placed at a disadvantage (compared to developing countries) if suitable alternatives cannot be found. This is highlighted by the fact that in 2005, when the developed countries should have completed the phaseout of methyl bromide, the developing countries would still be permitted to use methyl bromide on 80% of the base level. Unfortunately, there are very few viable alternatives that are technically and are economically feasible and also acceptable from a public health standpoint. Therefore the Montreal Protocol allowed for exemptions to the phaseout (e.g., the critical use exemption). In March of 2004, a meeting of the Parties to the Montreal Protocol was held in Montreal, Canada, during March 24-26, 2004 to address problems related to the methyl bromide phaseout such as nominations and granting conditions for Critical Use Exemptions (CUES). For examples, the United States made a CUE request after a thorough and comprehensive review process. The U.S. EPA will work with the USDA to fully support the U.S. nomination.

Table 3-1. Schedules of the phaseout of methyl bromide

Developed Countries	Developing Countries
1991: Base level	1995-98 average: Base level
1995: Freeze	2002: Freeze
1999: 75% of base	2003: Review of reductions
2001: 50% of base	2005: 80% of base
2003: 30% of base	2015: Phaseout
2005: Phaseout	

Source: U.S. Environmental Protection Agency

Four factors need to be considered when selecting and evaluating suitable alternatives to methyl bromide. The first factor is technical. Methyl bromide is quite versatile, fairly easy to apply, and can be effective against a wide range of pests (unlike most other pesticide, fumigant, or pest control methods). U.S. producers may consider using Integrated Pest Management (IPM) as an alternative to using methyl bromide. IPM is based on pest identification, and monitoring and establishing pest injury levels. However, a successful IPM program requires more information, analysis, planning, and know-how than does using methyl bromide.

The second factor is economic (the impact of alternatives on the profitability of the enterprise). While some alternatives may involve a high initial investment cost, especially considering the operating costs of new equipment, they might actually be more cost-effective in the long run. This is true because the cost for using methyl bromide is expected to rise in the future. A less effective alternative could be as profitable as using methyl bromide if the costs for using the alternative are sufficiently lower. For the economic factor, profitability needs to be examined.

The third factor is health and safety, and the fourth factor is environmental concerns. Given the heightened awareness of safety and environmental concerns (from both marketing and environmental perspectives), it is advisable to select alternatives that

are considered environmental friendly and pose no or minimal risks to users. For example, an alternative should not cause ozone depletion and global warming.

Turning our attention to the potential trade impact, it should be noted that international trade is an important component of the U.S. fruit and vegetable industry. In 1999, imports accounted for 11.6% of total U.S. fruit and vegetable consumption. The United States imposed ad valorem tariffs on imports of fresh vegetables. The U.S. ad valorem tariffs were 3.1% to 4.6% on fresh tomatoes, 3.0% on fresh bell peppers, and 2.1% to 10.6% on fresh cucumbers. Negotiations of trade agreements within the World Trade Organization (WTO) or as part of the Free Trade Area of the Americas (FTAA) could significantly lower these tariffs. As stated earlier, NAFTA has had a considerable impact on the levels of these tariffs. NAFTA, which went into force on January 1, 1994, is an agreement by the United States, Canada, and Mexico to phase out almost all restrictions on international trade and investment among the three countries. The United States and Canada were already well on the way to eliminating the barriers to trade and investment between them when NAFTA went into effect. The main new feature of NAFTA was the removal of most of the barriers between Mexico and the United States.

Fresh vegetable imports have been under scrutiny since before the implementation of NAFTA in 1994. During the first year of NAFTA, the import share of consumption for fresh fruits and vegetables remained at the pre-NAFTA level of about 10%. However, following the devaluation of the Mexican peso in December of 1994, U.S. imports of Mexican vegetables rose sharply. Mexican growers increased shipments to the United States because of poor domestic demand and more attractive prices in the United States. As a result of measured exports of fresh vegetables from Mexico, the

import share of U.S. domestic consumption of vegetables grew steadily from 10% in 1994 to 15% in 1998. In 1999 and into early 2000, low U.S. domestic prices slowed import volume and pushed the import market share down to 14%.

Several empirical studies in the literature on the analysis of international-trade issues have focused on partial equilibrium analysis. For example, spatial price equilibrium analysis attempts to predict changes in future trade flows, prices, consumption, and production for a commodity under governmental policies. The results allow the estimation of welfare benefits and costs by using the concept of economic surplus to individual countries from specific trade policies.

Under the partial equilibrium analysis, the assumption is that producers maximize their profits, consumers maximize their utilities, and marketing activities are competitive. Distortions come about only through governmental policies. There is no world price in this model because the price differs among regions by transportation costs, tariffs, and market imperfections. The amounts of consumption, production, exports, imports, and equilibrium prices in each region are determined simultaneously.

Research Problem

With an increase in the number of U.S. sponsored trade agreements and general trends toward opening the market, U.S. producers of fruits and vegetables may face increased competition from foreign sources. Changes in competitiveness could affect trade flows, which could change the structure and geographic distribution of the agricultural industries. International-trade agreements and competition among fruit and vegetable industries have increased. Also, the phaseout of methyl bromide places the United States at a disadvantage in trade with Mexico. Our study analyzes the impacts of international-trade agreements and the ban on methyl bromide by estimating the change

in location of agricultural production and by determining which countries will benefit and which countries will lose.

Hypotheses

Our main hypotheses were as follows:

- If a ban on methyl bromide is imposed without viable economic alternatives, then the production of these crops will decrease. Therefore the decrease in production causes the prices of fruits and vegetables in the United States to increase.
- The impact of NAFTA will decrease fruit and vegetable prices in the United States. Afterwards, the decrease in prices will cause an increase in the quantity demanded and a decrease in the domestic-quantity supplied.

Objectives

The first objective of our study is to estimate the impact of the phaseout of methyl bromide on consumers, producers, prices, productions, and revenues. The second objective of our study is to investigate the impact of NAFTA on the fruit and vegetable industry. By investigating the impacts of the international-trade issues, the model is expected to replicate the evolution of the fruit and vegetable industry.

Theoretical Framework

Following Mas-Colell (2000), in a competitive economy, consumers and producers act as price takers by regarding market prices as unaffected by their own actions. Building on a spatial equilibrium model developed by VanSickle et al., we conducted an investigation of the fruit and vegetable industry. This spatial equilibrium model satisfies a profit-maximizing condition, a utility-maximizing condition, and a market-clearing condition. These three conditions must be met for a competitive economy to be considered in equilibrium. The profit-maximizing condition states that each firm will choose a production plan that maximizes its profits, given the equilibrium prices of its outputs and inputs. The utility-maximizing condition requires that each consumer choose

a consumption bundle that maximizes utility, given the budget constraint imposed by the equilibrium prices and wealth. The market-clearing condition requires that at the equilibrium prices, the aggregate supply of each commodity equals the aggregate demand for that commodity. If excess supply or demand exists for a good at the going prices, the economy would not be at a point of equilibrium. At the equilibrium price that equates demand and supply, consumers do not wish to raise prices, and firms do not wish to lower them.

The partial equilibrium analysis assumes that the market for one good (or several goods), represents a small part of the overall economy. It is also assumed that the wealth effects in a small market will also be small, as the expenditure on the good is a small portion of a consumer's total expenditure. Moreover, given the small size of the market, any changes in this market are expected to have no or negative impact on prices in other markets. In terms of the partial equilibrium interpretation, we consider good g as the good whose market is being investigated, and denote the composite of all other goods as the numeraire. We normalize the price of the numeraire to equal one, and let p denote the price of good g. Each firm $j = 1, \ldots, J$ is able to produce good g from good k. The amount of the numeraire required by firm j to produce q_j units of good g is given by the cost function $c_j(q_j)$. Given equilibrium price p for good g, the profit-maximizing condition implies that firm j's equilibrium output level q_j must satisfy the profit-maximizing problem,

$$Max\ pq_j - c(q_j). \qquad (3\text{-}1)$$

Likewise the utility-maximizing condition implies that given the equilibrium price p for good g, consumer i's equilibrium consumption level x_i must satisfy the utility-maximizing problem, subject to the budget constraint,

$$Max\ u_i(x_i), \tag{3-2}$$

subject to

$$\Sigma_i\ px_i = m, \tag{3-3}$$

where m is the budget share.

Because of the market clearing condition assumed, the equilibrium price of good g will be price p at which the aggregate demand equals the aggregate supply,

$$x = q, \tag{3-4}$$

where x is an aggregate demand ($x = \Sigma_i\, x_i$) and q is an aggregate supply ($q = \Sigma_j\, q_j$).

Because consumers and producers are price takers, the inverses of the aggregate demand and supply functions are of interest. The inverse demand function, $P(x) = X^{-1}(x)$, gives the price that results in the aggregate demand of x. That is, when each consumer optimally chooses a consumer demand for good g at this price, total demand exactly equals x. At these individual demand levels, each consumer's marginal benefit from an additional unit of good g is exactly equal to $P(x)$. Moreover, given that the aggregate quantity x is efficiently distributed among the consumers, the value of the inverse demand function, $P(x)$, can also be viewed as the marginal social benefit of good g.

Likewise, inverse supply function, $p = Q^{-1}(q)$, gives the price that results in the aggregate supply of q. That is, when each firm chooses its optimal output level facing this price, the aggregate supply is exactly q. The inverse of the industry supply function can be viewed as the industry marginal cost function, which can be denoted by

$$C'(q) = Q^{-1}(q). \tag{3-5}$$

We get the inverse supply function (or the industry marginal cost function) from the profit-maximizing condition and the inverse demand function from the utility-maximizing condition. Then we can find the equilibrium price at which $p(x) = p(q)$, $X^{-1}(x) = Q^{-1}(q)$, or $P(x) = C'(x)$ as $x = q$ (Equation 3-4). Figure 3-1 represents the partial equilibrium analysis using the Marshallian graphical technique with the equilibrium price at the point of intersection of the aggregate demand and aggregate supply curves.

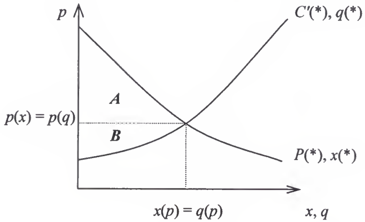


Figure 3-1. Aggregate demand and aggregate supply

Fundamental Theory of the Partial Equilibrium Model

In the partial equilibrium model, it is relatively easy to measure the change in the equilibrium outcome of a competitive market or the change in the level of social welfare, resulting from a change in underlying market conditions such as an improvement in technology, a new government international-trade policy, or the elimination of some existing market imperfection. The partial equilibrium model turns out the optimal consumption and production levels for good g that maximize the Marshallian aggregate surplus. Moreover, if price p and allocation $(x_1, \ldots, x_i, q_1, \ldots, q_j)$ constitute a competitive

equilibrium, then this allocation is Pareto optimal (which is the first fundamental theorem of welfare economics). A differential change ($dx_1, \ldots, dx_i, dq_1, \ldots, dq_j$) in the quantities of good g (consumed and produced) satisfies $dx = \Sigma_i\, dx_i = \Sigma_j\, dq_j$ (since $x = q$, Equation 3-4). The change in aggregate Marshallian surplus is then

$$dS = P(x)\,\Sigma_i\, dx_i - C'(q)\,\Sigma_j\, dq_j,$$
$$dS = [P(x) - C'(x)]\, dx. \tag{3-6}$$

It is sometimes of interest to distinguish between the two components of aggregate Marshallian surplus that accrue directly to consumers and producers. That is, if the set of active consumers of good g is distinct from the set of producers, then this distinction demonstrates something about the distributional effects of the change in the level of social welfare. There is a change in aggregate consumer surplus when consumers face effective price $\hat{p}$ and aggregate consumption $x(\hat{p})$, which is

$$dCS(\hat{p}) = [P(x) - \hat{p}]\, dx. \tag{3-7}$$

There is also a change in aggregate producer surplus when firms face effective price, $\hat{p}$, and aggregate production $q(\hat{p})$, which is

$$d\Pi(\hat{p}) = [\hat{p} - C'(q)]\, dq = [\hat{p} - C'(x)]\, dx. \tag{3-8}$$

We can see that the change in aggregate Marshallian surplus is the summation of the change in aggregate consumer surplus and the change in aggregate producer surplus, which can be written as

$$dS = dCS(\hat{p}) + d\Pi(\hat{p}). \tag{3-9}$$

We can also integrate Equation 3-9 to express the total value of the aggregate Marshallian surplus, the aggregate consumer surplus, and the aggregate producer surplus. By doing this, we get

$$S_0 + \int_0^x [P(s) - C'(s)]\, ds = \{ \int_0^{x(\hat{p})} [P(s) - \hat{p}\,]\, ds\} + \{\Pi_0 + \int_0^{q(\hat{p})} [\,\hat{p} - C'(s)]\, ds\},$$

$$S_0 + \int_0^x [P(s) - C'(s)]\, ds = \int_{\hat{p}}^{\infty} x(s)\, ds + \{\Pi_0 + \int_0^{q(\hat{p})} [\,\hat{p} - C'(s)]\, ds, \qquad (3\text{-}10)$$

where S_0 is a constant of integration equal to the value of the aggregate surplus. When there is no consumption or production of good g, Π_0 is a constant of integration equal to the value of the profits when $q_j = 0$ for all j and $S_0 = \Pi_0$ (which is equal to 0 if $c_j(0) = 0$ for all j). In Figure 3-1, the aggregate consumer surplus is depicted by area A and the aggregate producer surplus is depicted by Area B. The maximized aggregate Marshallian surplus is depicted by area A plus area B, which is exactly equal to the area lying vertically between the aggregate demand and supply curves for good g, up to equilibrium quantity x.

Impact of the Phaseout of Methyl Bromide

Since currently available alternatives of methyl bromide are more expensive, it can be postulated that in the absence of methyl bromide, cost of production is likely to increase. This can be represented in the model by an upwards shift in the aggregate supply curve, $C'_m(Z)$. Figure 3-2 shows that the new supply curve is $Z_m(P) = C'(Z) + C'_m(Z)$, where $C'_m(Z)$ is the addition marginal cost resulting from the phaseout of the methyl bromide. Figure 3-2 shows that the upward shift of the supply curve results in an increase in the equilibrium price (from P^* to P^{**}) and a decrease in the aggregate shipment quantity (from X^* to X^{**}).

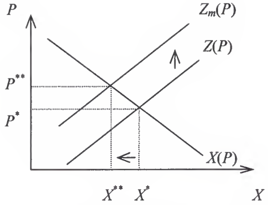


Figure 3-2. Partial equilibrium under effect of the phaseout of methyl bromide

Impact of NAFTA

The most important effect of trading with another nation is the economic gains that accrue to both parties as a result of trade. Without trade, each country has to make everything it needs, including those products it is not efficient at producing. On the other hand, when trade is permitted, each country can concentrate its efforts on producing exports in exchange for imports. Gains from trade arise from being able to purchase desired commodities or services from abroad cheaper than it would cost to produce them at home.

As pointed out by Schiavo-Campo (1978), countries trade among themselves because of differences in factor endowments. An analysis of the impact of different national endowments of production factors have upon international trade is summarized in the Heckscher-Ohlin Theorem. This theorem states that a country has a comparative advantage in producing commodities with a relatively abundant factor and importing commodities with a relatively scarce factor. However, there are many barriers to

international trade, including natural obstacles like the geographic distance between countries and the resulting costs of transport.

The best-known, and most frequently used, instrument of commercial policy (which is a man-made obstacle to international trade) is the tariff. Tariffs may be expressed in absolute dollars-and-cents terms (a specific tariff) or in relative terms as a percentage tax (ad valorem tariff). A tariff is an instrument that is used to economically separate the national market from the world economy by increasing the import price of a commodity over its world price (i.e., a tariff causes an increase in the domestic price, which is the main consequence of tariffs on production, consumption, income distribution, and trade).

The several effects of a tariff can be shown by means of supply-and-demand diagrams that are expanded to include import supply in addition to domestic supply. Figure 3-3 shows the market situation for a homogeneous product in the importing country. In the complete absence of foreign trade, the market would find its equilibrium at E_d, which is the intersection of domestic demand line D_d and domestic supply line S_d. The product would sell for price P_d. Consumers' surplus under the absence of trade (which is the differences between the market price and the maximum they would be willing to pay) is area P_dE_dL. Producers' surplus under the absence of trade (which is the difference between the market price and the minimum the producers would be willing to accept) is area ME_dP_w.

When trade is allowed, the imports increase product supply ($S_d + S_f$) and decrease the product price to consumers. Consequently, the market would find its new equilibrium at I (which is the intersection of domestic demand line D_d and domestic supply plus

foreign supply line $S_d + S_f$). The product would sell for price P_w. The imports are *AB* (which is the difference between total desired consumption and domestic production). Domestic production is *OA*, and total quantity demanded is *OB*. The decrease in price causes an increase in the consumption and a decrease in domestic production. Consumers' welfare gain is area $P_wIE_dP_d$, and domestic producers' welfare loss is area $P_wFE_dP_d$. The net gain from trade is area FIE_d.

When the domestic country imposes a tariff, the foreign supply is decreased, but the price of the product is increased. As a result, the market finds its new equilibrium at *J* (which is the intersection of domestic demand line D_d and domestic supply plus foreign supply with tariff line $S_d + S_f + T$). The product would sell for price P_{w+T}. The increase in price causes a decrease in the consumption and an increase in the domestic production. Consumption falls to *OD*, and domestic production rises to *OC*. Imports are cut on both accounts to *CD*. Consumers' welfare loss is area P_wIJP_{w+T}, domestic producers' welfare gain is area P_wFKP_{w+T}, and tariff revenue effect is area *GHJK*.

The tariff consumption effect (*BD*) is related to the price elasticity of demand. A highly elastic demand indicates that a change in price has a considerable effect on the amount that people wish to buy. On the other hand, a relatively inelastic demand means that a price change will lead to only a small change in the quantity demanded. If price elasticity is zero, the quantity will not change at all, regardless of the magnitude of the variation in the price of the product.

The effect from NAFTA (which is an agreement between the United States, Canada, and Mexico to phaseout almost all restrictions on international trade, including tariffs) will move the equilibrium point back to *I* and the supply line to the right (where

the supply of the product is domestic supply plus foreign supply line $S_d + S_f$). The product would sell for price P_w.

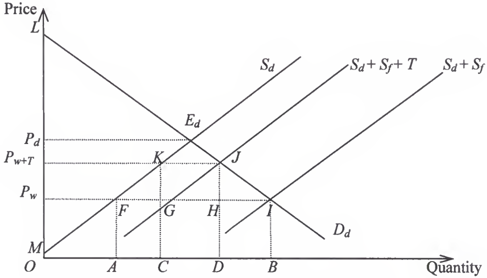


Figure 3-3. Partial equilibrium under the effect of tariff

Methodology

A partial equilibrium model can be used to evaluate the effects of a change in the industry on the production and marketing of various crops in various regions. In the VanSickle et al. model, these crops were modeled in a monthly model, considering production from each of the major producing regions in Florida and from other regions in the United States and Mexico. The model was developed to characterize crop production from these regions for the winter months in which Florida ships these commodities.

The VanSickle et al. model allocates crop production across regions based on delivered cost to regional markets, productivity, and regional demand structure in the United States. Inverse demand equations were used in the model based on work by Scott (1991) for squash, eggplant, and watermelons and from Chapter 2 for tomatoes, bell

peppers, cucumbers, and strawberries. Pre-harvest and post-harvest cost production costs were estimated for each production system and area by Smith and Taylor (2002). The cost budgets were constructed using a computerized budget generator program, AGSYS. Technical coefficients used in constructing the budgets were obtained by consultation with individual growers, county agents, and UF/IFAS researchers. Florida uses several double-cropping systems in which a primary crop is followed by a different (secondary) crop on the same unit of land. Transportation costs were included for delivering these products to each of the regional markets based on mileages determined by the Automap software and an estimation for a fully-loaded refrigerated truck carrying 40,000 pounds at $1.3072 per mile (VanSickle, et al., 1994).

The constrained optimization model was solved using GAMS software. After solving the VanSickle et al. model for a base solution for the 2000/2001 season, the budgets and yields were changed to reflect the costs of growing the crops using an alternative to methyl bromide. The results were compared to determine the impact that the phaseout of methyl bromide may have on the production and marketing of these crops.

In our study, we investigated the effect of the phaseout of methyl bromide on tomatoes, bell peppers, and eggplant in Florida and on strawberries grown in both Florida and California. Estimates of the impacts on production costs and yields from using alternatives to methyl bromide were determined from discussions with scientists attending USDA meetings (Carpenter and Lynch, 1998). For strawberries, California growers were assumed to have switched to Chloropicrin (with additional hand weeding) as a replacement to methyl bromide. Strawberry producers in West Central Florida were

assumed to have switched to a Telone C17/Devrinol herbicide combination. For tomatoes, Florida growers were assumed to have switched to a Telone C17/Chloropicirin/ Tillam herbicide combination. For eggplant and bell peppers, Florida growers were assumed to have switched to a Telone C17/Devrinol herbicide combination. Using Telone requires additional protective equipment that must be worn by applicators and field workers. Table 3-2 shows the impact of these alternatives to methyl bromide on pre-harvest cost and yield in each region in Florida and California. Other regions included in the model were assumed to be producing crops without using methyl bromide, and therefore would have no effect on costs and yields from the phaseout.

Table 3-2. Effect of the methyl bromide in Florida and California

State	Region	Pre-harvest Cost Impact ($/acre)	Percentage of Yield Reduction (%)
Florida			
	Dade County	(291)	10
	Palm Beach County	(115)	5
	Southwest Florida	(74)	10
	West Central	(139)	5
California			
	Northern California	653	20
	Southern California	653	20

Source: USDA

Next we investigated international trade by changing the production costs for Mexico to reflect the effect of NAFTA. Our baseline assumed a fixed tariff of $0.1 per unit of imported commodity, which was added to the post-harvest cost of production. We found that the impact of NAFTA would be the elimination of all such tariffs.

The VanSickle et al. model was solved using GAMS programming software. The analysis of the impacts from NAFTA and the ban on methyl bromide were conducted in

two parts. Our study updated the VanSickle et al. model to the 2000/2001 production season by using updated data and quantity elasticities estimated from the inverse demand analysis. This solution provided the baseline for comparison to other solutions where the parameters of the model were adjusted to reflect the impacts of NAFTA and the ban on methyl bromide.

For the first part of the analysis, the model was solved with parameters that assumed continued use of the tariff and methyl bromide. For the second part of the analysis, three scenarios beyond the baseline were solved with the model. The first scenario assumed the next best alternative, given projections on expected cost and yield impacts. The second scenario gave projections on the post-harvest production cost that was reduced for Mexico from the elimination of tariffs. The third scenario combined the impacts of NAFTA and the ban on methyl bromide. The adjustments that were made in the parameters reflect changes in production costs and yield by switching to alternatives to methyl bromide and changes in post-production costs for Mexico by switching to non-tariff trade.

The VanSickle et al. model was developed by modifying the North American winter vegetable market model developed by Spreen et al. (1995). For the demand side of the model, the commodities were assumed to be shipped to one of four demand regions of the United States, including the northeast, southeast, midwest, and west. These demand regions were represented by the New York City, Atlanta, Chicago, and Los Angeles wholesale markets, respectively. The commodities in the model were tomatoes, bell peppers, cucumbers, squash, eggplant, watermelon, and strawberries. There is an inverse demand equation for each commodity in each demand region with an assumption

that the slope of the demand function is constant over quantities. The model calculates total production costs by summing pre-harvest and post-harvest costs. The pre-harvest cost is the product of the number of acres planted and the per-acre pre-harvest costs. The post-harvest cost is the product of the number of acres planted, yield, and per-unit harvest and post-harvest costs. Alternatives are expected to have impacts on both yield and per-unit cost. Moreover, the model can calculate the transportation cost that is the product of the quantity of commodity shipped and the per-unit transportation cost.

The VanSickle et al. model can be characterized as a spatial equilibrium problem. By using the following indices the model can be mathematically stated as

region: $i = 1,\ldots,I$: index the 12 production points,

crops: $k = 1,\ldots,K$: index the seven crops being considered,

market: $j = 1,\ldots,J$: index the four market centers,

production systems: $ks = 1,\ldots,KS$: index the 16 production systems,

time: $m = 1,\ldots,M$: index the 12 months when the crop may be sold.

The demand for these crops is divided into four different markets. The inverse demand curve is represented for the markets as

$$P_{jkm} = a_{jkm} - b_{jkm}\, Q_{jkm}, \tag{3-11}$$

where P_{jkm} is the wholesale price per ton for crop k in market j in month m,

Q_{jkm} is the quantity of tons of crop k that is sold in market j in month m,

a_{jkm} is the demand curve's intercept,

b_{jkm} is the slope of the demand function.

This formulation assumes that the slopes of the demand functions are constant over all quantities. The model assumes that each region's production is a perfect substitute for

that of any other region. Moreover, the model assumes that the price of each commodity is a function of its own quantity alone and that the price is not affected by other crop prices and quantities that may be sold in that market in that month.

To compute the inverse demand function, demand flexibilities were based on wholesale price and arrival data for the various crops. The flexibilities are the uncompensated own quantity elasticities calculated from the Rotterdam Inverse Demand System (RIDS). The RIDS model satisfies the utility-maximizing condition. Using this information, the parameters for the slope and intercept of the demand equation can be calculated.

Let ψ_{jkm} = the demand flexibilities for crop k in market j in month m, where

$$\psi_{jkm} = (\partial P_{jkm} / \partial Q_{jkm})(Q_{jkm} / P_{jkm}). \tag{3-12}$$

The slope of the inverse demand equation is

$$\begin{aligned} -b_{jkm} &= (\partial P_{jkm} / \partial Q_{jkm}), \\ -b_{jkm} &= \psi_{jkm} (P_{jkm} / Q_{jkm}). \end{aligned} \tag{3-13}$$

After b_{jkm} had been calculated, a_{jkm} can be estimated from

$$a_{jkm} = P_{jkm} + b_{jkm} Q_{jkm}. \tag{3-14}$$

For the supply side, the production points are Florida, California, Mexico, Texas, South Carolina, Virginia, Maryland, Alabama, and Tennessee. Florida was separated into four producing areas: Dade County, Palm Beach County, Southwest Florida, and West Central Florida. Mexico was separated into two producing areas: the states of Sinaloa and Baja California. California was separated into two producing areas: Southern California and Northern California. Also, there are 16 cropping systems, which include both single and double cropping systems. The single cropping systems include tomatoes, fall tomatoes, spring tomatoes, bell peppers, fall peppers, spring peppers, cucumbers,

squash, eggplant, and strawberries. The double cropping systems include tomatoes and cucumbers, tomatoes and squash, tomatoes and watermelons, bell peppers and cucumbers, bell peppers and squash, and bell peppers and watermelons. The model assumes that all producers in a particular region use the same production technology (with the same yields and costs), and that crops are produced with fixed-proportion production functions.

The production costs in this model include pre-harvest cost, harvest cost, post-harvest cost, and transportation cost. The model calculates total production costs by summing pre-harvest and post-harvest costs. The pre-harvest cost is the product of the number of acres planted and the per-acre pre-harvest cost (in which we can apply the alternative effect). The post-harvest cost is the product of the number of acres planted, yield, and per-unit harvest and post-harvest costs. The pre-harvest cost includes both operating costs and fixed costs. The operating costs include fertilizer, fumigant, fungicide, herbicide, insecticide, labor, surfactant, transplants, machinery, machinery labor, scouting, stakes, plastic string, plastic mulch, farm vehicles, and interest on working capital. The fixed costs include land rent, machinery fixed cost, supervision cost, and overhead cost. Harvest and post-harvest costs include harvesting, cooling, packing, transportation to shipment point, and marketing costs. These costs for Mexico also include transportation to the U.S. border and all tariffs and fees to cross the border into the United States. An average per-mile transportation cost of $1.31 was calculated using information from the USDA Agricultural Marketing Service. These costs include truck brokers' fees for shipments in truckload volume to a single destination, based on costs of shipping from the point of origin to the point of destination, and do not include

any costs of returning the truck to the point of origin. Per-unit transportation cost can be calculated from the product of the distance between supply region *i* to demand region *j* and the transportation cost of per-unit, per-mile.

The VanSickle et al. model can determine which regions and which production systems will achieve the most profit from producing each crop in each month (up to the point where growers have used all the available land). The model attempts to maximize producers' return and consumers' benefits while taking into account the constraint on the amount of land available in each region (i.e., a demand constraint) and that the amount sold to consumers cannot be greater than the amount supplied (i.e., a supply constraint). Therefore, the model finds the equilibrium consumption of each commodity in each demand region. On the supply side, the model calculates the optimal production in acreage and the quantity of each commodity produced. This model also finds the optimal level of shipments. By using these optimal solutions, price, production, and revenue can be calculated. Altogether, the impacts on consumers, producers, price, production, and revenue can be investigated using this model.

By assuming that all producers in a particular region use the same production technology, it also can be assumed that they will have the same yields and costs. The model uses data on each region's crops, yields, constraints, and marketing windows to determine which regions and which production systems are best for achieving the most profit from producing each crop in each month (up to the point where the growers have used all the available land). The model allows growers to choose which of the four demand market areas to use, given the different market prices and transportation costs for each market. The model seeks to maximize producers' returns and consumers' benefits

while taking into account that there are constraints on the amount of land available in each region and that the amount sold to consumers cannot be greater than the amount supplied.

The optimal solution to this model provides the equilibrium consumption of each commodity in every month for each demand region; the optimal level of shipments between each supply area and each demand region; the optimal production of each cropping system, by production area; and the quantity of each commodity produced in each supply region, by month.

The VanSickle et al. model is simulated by using the profit-maximizing problem to find the optimal production that satisfies the competitive equilibrium market, given the inverse demand equation, supply constraint, and demand constraint. From the first-order condition, the profit-maximizing condition is satisfied, as the inverse demand equation equals the total marginal cost (which includes both the marginal cost of production and the marginal cost of transportation). This model applies elasticities calculated from an inverse demand system that solves the utility-maximizing problem (so that the utility-maximizing condition is satisfied). Moreover, the market clearing condition is satisfied as both supply and demand constraints are binding.

To simplify the model, the VanSickle et al. model is simulated by using the profit-maximizing problem to find the optimal production that satisfies the competitive equilibrium, Equation 3-1. The quadratic programming model can be written as

$$\text{Max} \sum_{j=1}^{J} \sum_{k=1}^{K} \sum_{m=1}^{12} [a_{jkm} Q_{jkm} - (1/2) b_{jkm} Q^2_{jkm}] - \sum_{i=1}^{I} \sum_{ks=1}^{KS} C1_{iks} W_{iks}$$
$$- \sum_{i=1}^{I} \sum_{ks=1}^{KS} \sum_{k=1}^{K} \sum_{m=1}^{12} C2_{iksk} Z_{ikm} - \sum_{i=1}^{I} \sum_{j=1}^{J} \sum_{k=1}^{K} \sum_{m=1}^{12} C3_{ijkm} X_{ijkm} \qquad (3\text{-}15)$$

subject to

$$Z_{ikm} = \sum_{ks=1}^{KS} d_{ikskm} W_{iks}, \tag{3-16}$$

$$\sum_{j=1}^{J} X_{ijkm} \leq Z_{ikm}, \tag{3-17}$$

$$\sum_{i=1}^{I} X_{ijkm} \geq Q_{jkm}, \tag{3-18}$$

Q_{jkm}, W_{ik}, Z_{ikm}, $X_{ijkm} \geq 0$ for all of i, j, k, m, and ks,

where d_{ikskm} = per-acre yield of commodity k in month m from cropping system ks in supply region i,

W_{iks} = number of acres planted of cropping system ks in supply region i,

U_{kskm} = the production of commodity k in supply region i and month m for cropping system ks,

$C1_{iksk}$ = per acre pre-harvest production cost of commodity k using cropping system ks in supply region i,

Z_{ikm} = the total supply of commodity k from supply region i in month m,

Q_{jkm} = the total demand of commodity k at demand region j in month m,

$C2_{iksk}$ = per-unit harvest and post-harvest costs associated with commodity k using cropping system ks in supply region i,

X_{ijkm} = quantity of commodity k shipped from supply region i to demand region j in month m,

$C3_{ijkm}$ = per-unit transportation cost of commodity k shipped from supply region i to demand region j in month m.

The inverse demand equation, Equation 3-11, Price = $a_{jkm} - b_{jkm}\, Q_{jkm}$.

$$\text{Total cost of production} = \sum_{i=1}^{I}\sum_{ks=1}^{KS} C1_{iks}\, W_{iks} + \sum_{i=1}^{I}\sum_{ks=1}^{KS}\sum_{k=1}^{K}\sum_{m=1}^{12} C2_{iksk}\, Z_{ikm}. \quad (3\text{-}19)$$

$$\text{Cost of transportation} = \sum_{i=1}^{I}\sum_{j=1}^{J}\sum_{k=1}^{K}\sum_{m=1}^{12} C3_{ijkm}\, X_{ijkm}. \quad (3\text{-}20)$$

We can derive the VanSickle et al. model from the Lagrangean equation

$$\begin{aligned} L = & \sum_{j=1}^{J}\sum_{k=1}^{K}\sum_{m=1}^{12} [a_{jkm}\, Q_{jkm} - (1/2) b_{jkm}\, Q^2_{jkm}] - \sum_{i=1}^{I}\sum_{ks=1}^{KS} C1_{iks}\, W_{iks} \\ & - \sum_{i=1}^{I}\sum_{ks=1}^{KS}\sum_{k=1}^{K}\sum_{m=1}^{12} C2_{iksk}\, Z_{ikm} - \sum_{i=1}^{I}\sum_{j=1}^{J}\sum_{k=1}^{K}\sum_{m=1}^{12} C3_{ijkm}\, X_{ijkm} \\ & + \sum_{i=1}^{I}\sum_{k=1}^{K}\sum_{m=1}^{12} s_{ikm} \left(\sum_{ks=1}^{KS} d_{ikskm}\, W_{iks} - Z_{ikm} \right) \\ & + \sum_{i=1}^{I}\sum_{k=1}^{K}\sum_{m=1}^{12} g_{ikm} \left(Z_{ikm} - \sum_{j=1}^{J} X_{ijkm} \right) \\ & + \sum_{j=1}^{J}\sum_{k=1}^{K}\sum_{m=1}^{12} u_{jkm} \left(\sum_{i=1}^{I} X_{ijkm} - Q_{jkm} \right), \end{aligned} \quad (3\text{-}21)$$

where g_{ikm} and u_{jkm} are the Lagrange multipliers.

Both constraints satisfy the regularity condition of the Kuhn-Tucker Theorem as they are linear. From the first-order condition with Q_{jkm}, the Kuhn-Tucker condition is

$$\partial L / \partial Q_{jkm} = a_{jkm} - b_{jkm}\, Q_{jkm} - u_{jkm} \le 0;\ Q_{jkm} \ge 0;\ (\partial L / \partial Q_{jkm}) Q_{jkm} = 0. \quad (3\text{-}22)$$

Let $Q_{jkm} > 0$, so that $\partial L / \partial Q_{jkm} = 0$. Therefore,

$$u_{jkm} = a_{jkm} - b_{jkm}\, Q_{jkm}. \quad (3\text{-}23)$$

The Lagrange multiplier for the demand constraint is the market price, $u_{jkm} = P_{jkm}$. Consequently, we can see that this model satisfies the utility-maximizing condition.

From the first-order condition with W_{iks}, the Kuhn-Tucker condition is

$$\partial L / \partial W_{iks} = s_{ikm} \sum_{ks=1}^{KS} d_{ikskm} - \sum_{ks=1}^{KS} C1_{iks} \leq 0;$$
$$W_{iks} \geq 0; (\partial L / \partial W_{iks}) W_{iks} = 0. \tag{3-24}$$

Let $W_{iks} > 0$ to get a trial solution, so that $\partial L / \partial W_{iks} = 0$. Therefore,

$$s_{ikm} = \sum_{ks=1}^{KS} C1_{iks} / \sum_{ks=1}^{KS} d_{ikskm}. \tag{3-25}$$

The Lagrange multiplier for the acreage equation, s_{ikm}, is the marginal cost of pre-harvest production.

From the first-order condition with Z_{ikm}, the Kuhn-Tucker condition is

$$\partial L / \partial Z_{ikm} = g_{ikm} - C2^{*}_{ikm} - s_{ikm} \leq 0; Z_{ikm} \geq 0; (\partial L / \partial Z_{ikm}) Z_{ikm} = 0, \tag{3-26}$$

where $C2^{*}_{ikm} = \partial \left(\sum_{ks=1}^{KS} C2_{iksk} Z_{ikm} \right) / \partial Z_{ikm}$, for $m = 1, \ldots, 12$.

Let $Z_{ikm} > 0$, so that $\partial L / \partial Z_{ikm} = 0$. From Equation 3-25, we get

$$g_{ikm} = C2^{*}_{ikm} + s_{ikm}$$
$$g_{ikm} = C2^{*}_{ikm} + \left(\sum_{ks=1}^{KS} C1_{iks} / \sum_{ks=1}^{KS} d_{ikskm} \right). \tag{3-27}$$

The Lagrange multiplier for the supply equation, g_{ikm}, is the total marginal cost of production.

From the first-order condition with g_{ikm}, the Kuhn-Tucker condition is

$$\partial L / \partial g_{ikm} = Z_{ikm} - \sum_{j=1}^{J} X_{ijkm} \geq 0; g_{ikm} \geq 0; (\partial L / \partial g_{ikm}) g_{ikm} = 0, \tag{3-28}$$

Let $g_{ikm} > 0$, so that $\partial L / \partial g_{ikm} = 0$. Therefore,

$$Z_{ikm} = \sum_{j=1}^{J} X_{ijkm}. \tag{3-29}$$

Equation 3-29 implies that the total supply of commodity *k* from supply region *i* in month *m* equals the aggregate for all demand regions of the quantity of commodity *k* shipped from supply region *i* to demand region *j* in month *m*.

From the first order condition with u_{jkm}, the Kuhn-Tucker condition is

$$\partial L / \partial u_{jkm} = \sum_{i=1}^{I} X_{ijkm} - Q_{jkm} \geq 0;\ u_{jkm} \geq 0;\ (\partial L / \partial u_{jkm})u_{jkm} = 0; \tag{3-30}$$

Let $u_{jkm} > 0$, so that $\partial L / \partial u_{jkm} = 0$. Therefore,

$$Q_{jkm} = \sum_{i=1}^{I} X_{ijkm}. \tag{3-31}$$

Equation 3-31 implies that the total demand of commodity *k* at demand region *j* in month *m* equals the aggregate for all supply regions of the quantity of commodity *k* shipped from supply region *i* to demand region *j* in month *m*.

From Equations 3-29 and 3-31, we can prove that the market-clearing condition is satisfied,

$$X_{ijkm} = X_{ijkm}$$

$$\sum_{i=1}^{I}\sum_{j=1}^{J} X_{ijkm} = \sum_{i=1}^{I}\sum_{j=1}^{J} X_{ijkm}$$

$$\sum_{j=1}^{J}\sum_{i=1}^{I} X_{jikm} = \sum_{i=1}^{I}\sum_{j=1}^{J} X_{ijkm}$$

$$\sum_{j=1}^{J} Q_{jkm} = \sum_{i=1}^{I} Z_{ikm} \tag{3-32}$$

So the first-order condition of this model satisfies the market-clearing condition of the competitive equilibrium at which aggregate demand equals aggregate supply.

From the first-order condition with s_{ikm}, we get

$$\partial L / \partial s_{ikm} = \sum_{ks=1}^{KS} d_{ikskm} W_{iks} - Z_{ikm} = 0. \tag{3-33}$$

From Equation 3-29, we get

$$\sum_{ks=1}^{KS} d_{ikskm} W_{iks} = \sum_{j=1}^{J} X_{ijkm}. \tag{3-34}$$

From the first-order condition with X_{ijkm}, the Kuhn-Tucker condition is

$$\partial L / \partial X_{ijkm} = u^*_{ijkm} - g^*_{ijkm} - C3_{ijkm} \leq 0;\ X_{ijkm} \geq 0;\ (\partial L / \partial X_{ijkm})X_{ijkm} = 0, \tag{3-35}$$

where $u^*_{ijkm} = u_{jkm}$ for $i = 1,\ldots, I$ and $g^*_{ijkm} = g_{ikm}$ for $j = 1,\ldots, J$.

To get a trial solution, we let $X_{ijkm} > 0$, so that $\partial L / \partial X_{ijkm} = 0$. By using Equations 3-23, 3-27, and 3-31, where u_{jkm} is the same for all of i, we get

$$a_{jkm} - b_{jkm} \left(\sum_{i=1}^{I} X_{ijkm} \right) = C2^*_{ikm} + \left(\sum_{ks=1}^{KS} C1_{iksk} / \sum_{ks=1}^{KS} d_{ikskm} \right) + C3_{ijkm} \tag{3-36}$$

Equation 3-36 ensures the profit-maximizing condition where price equals the marginal cost.

From Equation 3-34, the first-order condition of this model satisfies the profit-maximizing condition of the competitive equilibrium. This model solves the competitive equilibrium problem by simulating X_{ijkm} and W_{iks}, which satisfies Equation 3-32, 3-34, and 3-36. By using the optimal solution of X^*_{ijkm}, we can find the total demand, Q_{jkm}, by using Equation 3-31. We can find the total supply, Z_{ikm}, by using Equation 3-29, and price, P_{jkm}, by using Equation 3-23.

This model can be represented by using the Marshallian graphical technique with the equilibrium price as the point of intersection of the aggregate demand and aggregate supply curves. In addition, this model is Pareto optimal because the aggregate

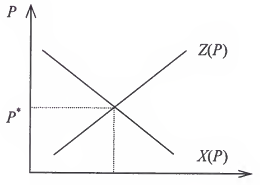
Marshallian surplus is maximized. From Figure 3-4, demand curve $X(P)$ can be defined by using the inverse demand function,

$$X(P) = P\left(\sum_{j=1}^{J} Q_{jkm}\right). \tag{3-37}$$

The supply curve $Z(P)$ for each production region can be defined by using the marginal cost function,

$$Z(P) = C'\left(\sum_{i=1}^{I} Z_{ikm}\right). \tag{3-38}$$

From the point of intersection of the aggregate demand and aggregate supply curves, we can find the equilibrium price, P^*, and the level of the aggregate shipment quantity, X, where $X = \sum_{i=1}^{I} \sum_{j=1}^{J} X_{ijkm}$.



$$\sum_{j=1}^{J} Q_{jkm} = \sum_{i=1}^{I} Z_{ikm}$$

Figure 3-4. Partial equilibrium of aggregate demand and aggregate supply

Empirical Results

The solution to the VanSickle et al. model included shipments, by month and crop, from each producing area to each market; the planted acreage, production, and revenues to each cropping system in each production area; and the equilibrium prices and quantity consumed, by month and crop, in each of the four market areas. The baseline solution performed reasonably well in replicating the observed pattern of shipments and acres planted for the 2000/2001 production season.

The baseline acreage planted to each crop in each of the major producing areas is shown in Table 3-3, which includes estimates of the expected inputs from the ban on methyl bromide alone (first scenario), NAFTA alone (second scenario), and the combination of the ban on methyl bromide and NAFTA together (third scenario). Percentage changes in production and revenues, compared with the baseline for each crop in each area, are shown in Table 3-5. Changes in production, compared with the baseline, by area, are shown in Table 3-4. Changes in revenues, compared with the baseline, by crop, in each area, are shown in Table 3-6. Changes in production and revenues, compared with the baseline, by area, are shown in Table 3-7. Changes in average prices, compared with the baseline, by crop, are shown in Table 3-8. Results show that significant effects may be expected across producing areas for all crops. Percentage changes in consumer demand for each commodity in each market, compared with the baseline, are shown in Table 3-9.

Tomatoes

Tomato production in Dade and Palm Beach Counties in Florida and in the Alabama/Tennessee region is expected to cease in every scenario. California is expected

to cease tomato production under the second scenario. Mexico is expected to increase its tomato producing acreage significantly, especially as a result of NAFTA. For example, the planted acreage of tomatoes in Baja is expected to increase from 5,369 acres to 27,583 acres (Table 3-3). The results for Mexico in the third scenario (under both NAFTA and the ban on methyl bromide) are not significantly different from the second scenario, since Mexico already enjoys significant gains from NAFTA. South Carolina, West Central Florida, and Southwest Florida are the only U.S. domestic producers that are expected to gain under the third scenario.

Results from Table 3-5 show that total production of tomatoes across all areas in the United States is expected to decrease by 7.11%, 41.88%, and 42.77% in the first, second, and third scenarios, respectively. On the other hand, tomato production in Mexico is expected to increase by 13.42%, 64.10%, and 68.50% in the first, second, and third scenarios, respectively.

The total revenues that growers receive for tomatoes are expected to decrease by \$1.1 million under the first scenario, to decrease by \$3.6 million under the second scenario, and to increase by \$1.6 million under the third scenario (Table 3-6). Florida will suffer the greatest loss in tomato shipping point revenues under the first scenario, with a loss of \$56.9 million. California will suffer the greatest loss in tomato shipping point revenues under the second scenario, with a loss of \$286 million. On the other hand, Mexico will increase their shipping point revenues by \$67.2 million under the first scenario, by \$332.7 million under the second scenario, and by \$353.7 million under the third scenario. Two significant conclusions to draw from these results for tomatoes are that the impact from NAFTA in Mexico is more significant than the impact from the ban

on methyl bromide and that Mexico will gain market share and shipping point revenues. The average wholesale price of tomatoes is expected to increase by 1.46% under the first scenario, to decrease by 0.52% under the second scenario, and to increase by 0.82% under the third scenario (Table 3-8).

On the demand side, Table 3-9 shows that consumer demand of tomatoes in every market is expected to decrease under the first scenario with the highest decrease in the Chicago market (1.44%) and the lowest decrease in the Los Angeles market (0.82%). The increase in the percentage change in the consumer demand of tomatoes under the second scenario is highest in the Atlanta market (1.26%) and is lowest in the New York market (0.51%). In the third scenario, the consumer demand of tomatoes is expected to increase in the Atlanta and Los Angeles markets and to decrease in Chicago and New York markets because the impact of the methyl bromide ban is higher than the impact of NAFTA in the Chicago and New York markets.

Bell peppers

Banning methyl bromide will have a negative impact on Florida. For example, the planted acreage of bell peppers is expected to decrease from 7,175 acres to 6,986 acres in Palm Beach County and to decrease from 10,997 acres to 9,499 acres in West Central Florida (Table 3-3). On the other hand, methyl bromide ban is expected to have a positive impact on Texas and Mexico, offsetting some of the loss experienced in Florida. The planted acreage of bell peppers is expected to increase from 12,680 acres to 14,458 acres in Texas and to increase from 13,600 acres to 13,901 acres in Mexico.

Under the first scenario, total production of bell peppers is expected to decrease by 1.04% (Table 3-5). Total shipping point revenues for bell peppers are expected to decrease by $6.6 million, with Florida suffering a $17.1 million loss in shipping point

revenues (Table 3-6). Shipping point revenues in Texas and Mexico are expected to increase by $8.2 million and $2.3 million, respectively. The average wholesale price of bell peppers under the first scenario is expected to increase by 1.35% (Table 3-8). Consumer demand of bell peppers in every market is expected to decrease with the highest percentage change of consumer demand for bell peppers will be in the New York market, which is expected to decrease by 5.91% (Table 3-9).

Under second scenario, bell pepper production in Mexico is expected to increase by 2.67%, while bell pepper production in Florida is expected to decrease by only 0.78% (Table 3-5). Table 3-8 shows that the average wholesale price of bell peppers under the second scenario is expected to decrease by 0.24%. Table 3-9 shows that consumer demand of bell peppers under the second scenario is expected to increase in every market.

Under the third scenario, the planted acreage of bell peppers in Mexico is expected to increase significantly from 13,600 acres to 14,551 acres (Table 3-3). As a result, production of bell peppers in the United States is expected to decrease by 2.85% (Table 3-5). The impact of NAFTA is expected to reduce the impact of the methyl bromide ban in the U.S. domestic market (e.g., production of bell peppers is expected to increase by 10.12% in Texas and to decrease by 8.37% in Florida). In addition, the total shipping point revenues for bell peppers are expected to decrease by $4.3 million, with shipping point revenues for bell peppers in Mexico increasing by $6.1 million and shipping point revenues for bell peppers in the United States decreasing by $10.4 million (Table 3-6). The average wholesale price of bell peppers under the third scenario is expected to increase by 0.90% (Table 3-8). Consumer demand of bell peppers in every market is expected to decrease, except in the Los Angeles market, which is expected to increase by

0.84% (Table 3-9), due to the greater impact of NAFTA as opposed to the lower impact of the methyl bromide in the Los Angeles market.

Cucumbers

Florida's 6,693 baseline acreage of cucumber production in Palm Beach County is expected to increase to 6,986 acres under the first scenario, to 6,769 acres under the second scenario, and to 6,829 acres under the third scenario (Table 3-3). Double cropping of cucumbers and bell peppers can increase total production of cucumbers in Florida. Cucumber production in Florida is expected to increase by 4.38% under the first scenario, by 1.14% under the second scenario, and by 2.04% under the third scenario (Table 3-5). Cucumber production in Mexico is expected to increase by 2.26% under scenario one and to increase by 2.83% under scenarios two and three.

Total shipping point revenues for cucumbers are expected to increase under all three scenarios; that is, by $917,980 under the first scenario, by $1.4 million under the second scenario, and by $941,490 under the third scenario (Table 3-6). Florida's shipping point revenues for cucumbers are expected to decrease by $79,510 under the first scenario, to increase by $104,430 under the second scenario, and to decrease by $302,210 under the third scenario. Table 3-8 shows that the average wholesale price of cucumbers is expected to decrease by 0.40%, 0.65%, and 0.36% under these three scenarios, respectively.

Table 3-9 shows that the consumer demand of cucumbers is expected to increase in every market under the first scenario because of the decrease in the price of cucumbers. Under the second scenario, the consumer demand of cucumbers is expected to increase in every market. Under the third scenario, the consumer demand of cucumbers in every

market, except the Los Angeles market, is expected to decrease, as the Los Angeles market receives more benefits from NAFTA than do the other markets.

Squash

The 3,637 planted baseline acres of squash in Southwest Florida are expected to increase to 4,423 acres under the first scenario, to 4,286 acres under the second scenario, and to 4,568 acres under the third scenario (Table 3-3). On the other hand, the planted acreage of squash in Dade County is expected to decrease in every scenario from 8,081 acres to 7,880 acres under the first scenario, to 7,647 acres under the second scenario, and to 7,749 acres under the third scenario.

Squash production in Mexico is expected to decrease by 0.76% under the first scenario, but is expected to increase by 1.46% under the second scenario and by 1.85% under the third scenario (Table 3-5). Squash production in Florida is expected to increase by 4.99%, 1.83%, and 5.11% under these three scenarios, respectively. Florida's total shipping point revenues for squash are expected to increase by $327,680 under the first scenario, by $322,760 under the second scenario, and by $185,970 under the third scenario, while Mexico's shipping point revenues are expected to decrease by $145,080 under the first scenario, to increase by $125,260 under the second scenario, and to increase by $198,630 under the third scenario (Table 3-6).

Table 3-8 shows that the average wholesale price of squash is expected to decrease by 0.18% under the first scenario, by 0.50% under the second scenario, and by 0.41% under the third scenario. Table 3-9 shows that the consumer demand of squash is expected to increase under these three scenarios in every market. The highest percentage change in the consumer demand of squash is in the New York market.

Eggplant

The 5,327 baseline acres of eggplant planted in Palm Beach County are expected to decrease to 5,132 acres under the first scenario, to 5,247 acres under the second scenario, and to 5,075 acres under the third scenario (Table 3-3). On the other hand, eggplant production in Mexico is expected to increase by 4.69% under the first scenario, by 5.96% under the second scenario, and by 9.75% under the third scenario to offset the loss of production in Florida (Table 3-5).

Total shipping point revenues for eggplant are expected to decrease by $2.5 million under the first scenario and by $2.1 million under the third scenario (Table 3-6). On the other hand, under the second scenario, the total shipping point revenues for eggplant are expected to increase by $340,060, as Mexico gains $1.2 million and Florida loses $847,960 in shipping point revenues. The average wholesale price of eggplant is expected to decrease by 0.36% under the second scenario, but is expected to increase by 1.26% under the first scenario and by 0.87% under the third scenario (Table 3-8).

The consumer demand of eggplant in every market is expected to decrease under the first scenario with the highest decrease in the Atlanta market (11.55%) and to increase under the second scenario with the highest increase in the Los Angeles market (2.34%). Under the third scenario, the consumer demand of eggplant in every market is expected to decrease, except in the Los Angeles market, which is expected to increase by 1.90% (Table 3-9), due to the greater impact of NAFTA as opposed to the impact of the methyl bromide ban.

Watermelons

Table 3-3 shows that the 1,812 planted baseline acres of watermelon in West Central Florida are expected to decrease to 593 acres under the first scenario, to 1,694

acres under the second scenario, and to 923 acres under the third scenario. This occurs because of the decrease in the production of double cropped of watermelons and bell peppers. The 17,338 baseline acres of watermelon in Southwest Florida are expected to increase to 18,340 acres under the first scenario, to 18,002 acres under the second scenario, and to 17,899 acres under the third scenario as a result of the increase in the production of double cropped of watermelons and tomatoes.

Total production of watermelons is expected to decrease by 0.76% under the first scenario and by 1.44% under the third scenario (Table 3-5). Consequently, the average wholesale price of watermelons is expected to increase by 5.13% under the first scenario and by 5.39% under the third scenario (Table 3-8). In contrast, under the second scenario, total production of watermelons is expected to increase by 2.91%, and the average wholesale price of watermelons is expected to decrease by 1.42%.

Total shipping point revenues for watermelons are expected to decrease by $7.9 million under the first scenario, by $976,981 under the second scenario, and by $5.7 million under the third scenario (Table 3-6). Consumer demand of watermelons is expected to increase in the first and third scenarios in every market (Table 3-9). On the other hand, the consumer demand of watermelons is expected to increase in every market under the second scenario, with the highest impact in the Atlanta market.

Strawberries

The model only estimates the impact of the methyl bromide ban for strawberries since tariffs are not currently collected on imports. The impact on California is significant because of the high cost and high productivity of the current production systems in California. Strawberry production in Northern California is expected to cease under the first scenario, and the planted acreage of strawberries in Southern California is

expected to decrease from 10,518 acres to 7,659 acres (Table 3-3). On the other hand, the planted acreage of strawberries in Florida is expected to increase from 4,545 acres to 4,692 acres under the first scenario. Total production of strawberries is expected to decrease by 41.06% under the first scenario (Table 3-5). The production of strawberries is expected to decrease by 51.62% in California and to increase by 3.24% in Florida.

Table 3-6 shows that total shipping point revenues for strawberries are expected to decrease by $245.4 million, with California suffering a $263.3 million loss in shipping point revenues. The average wholesale price of strawberries is expected to increase by 12.78% (Table 3-8). Consumer demand for strawberries in every market is expected to decrease under the impact of the methyl bromide ban, with the highest decrease in the Atlanta market at 66.57% (Table 3-9).

Aggregate impacts

Total production of the fruits and vegetables included in this model is expected to decrease by 7.97% under the first scenario, to increase by 0.08% under the second scenario, and to decrease by 7.26% under the third scenario (Table 3-4). Consequently, consumer surplus is expected to decrease under the first and third scenarios and to increase under the second scenario.

Total production in the United States is expected to decrease by 16.21% under the first scenario, by 21.93% under the second scenario, and by 34.22% under the third scenario (Table 3-4). California is expected to suffer the greatest loss in production. Tomato production in California is expected to cease under the second scenario, and strawberry production in California is expected to cease under the first scenario. Total production in California is expected to decrease by 31.12% under the first scenario, by 42.43% under the second scenario, and by 72.15% under the third scenario. On the other

hand, total production in Mexico is expected to increase by 11.01%, 50.74%, and 54.78% under the first, second, and third scenarios, respectively.

Under the first scenario, shipping point revenues are expected to decrease by $70.9 million in Florida, by $272.7 million in California, by $20.5 million in Alabama and Tennessee, and by $700,600 in Virginia and Maryland (Table 3-7). In contrast, shipping point revenues are expected to increase by $8.3 million in Texas, by $19.2 million in South Carolina, and by $71.5 million in Mexico. However, these gains do not offset the loss expected under the first scenario. As a result, total revenues are expected to decrease by $265.9 million. Under the second scenario, Mexico's shipping point revenues are expected to increase by $336.9 million, while U.S. total shipping point revenues are expected to decrease by $354.1 million. Under the third scenario, U.S. total shipping point revenues are expected to decrease by $623.4 million, with California shippers losing $549.3 million. Mexico's shipping point revenues are expected to increase by $363.4 million.

Table 3-9 shows that consumer demand for tomatoes, bell peppers, eggplant, watermelon, and strawberries is expected to decrease under the first scenario. The consumer demand of every commodity, except strawberries, is expected to increase under the second scenario. The highest impacts on the consumer demand for eggplant, watermelon and strawberries will be in the Atlanta market.

Conclusions

An economic model of the fruit and vegetable industry was used to determine the projected impacts of NAFTA and the methyl bromide ban. Methyl bromide has been a critical soil fumigant in the production of many agricultural commodities. Tomatoes, bell peppers, eggplant, squash, cucumbers, strawberries, and watermelons are the crops with

the greatest potential of being impacted under the first scenario. Florida is a major supplier of these products, and the methyl bromide ban would adversely affect the competitive position of Florida in these markets. Much of the lost production would move to Mexico. In addition, Texas could benefit from increased production of bell peppers, and South Carolina could benefit from increased production of tomatoes.

The production of strawberries in California would be expected to decrease under the first scenario, and the production of tomatoes in California would be eliminated under the second scenario. Even though Texas does not use methyl bromide in the production of bell peppers, its production of bell peppers would not increase much.

The main new feature of NAFTA was the removal of most of the trade barriers between Mexico and the United States. As a result, total production in Mexico could increase by more than 50%. For example, production of tomatoes in California could be eliminated, while production of tomatoes in Baja could increase by more than 400%. These losses could devastate U.S. agriculture because much of the lost production would move to Mexico, especially the production of tomatoes. The consumer demand in every commodity in every market would increase from the benefit of increased imports from Mexico under the second scenario.

Mexico would become the major supplier of fresh vegetables because of NAFTA and the Montreal Protocol agreements, which allow Mexico an additional 10 years to use methyl bromide. Overall, with the advantage from NAFTA, Mexico will be the primary beneficiary of the ban on methyl bromide because they will likely use methyl bromide to increase production. This could cause a large shift in production away from the United States to Mexico.

Table 3-3. Planted acreage in the baseline model, in the methyl bromide ban model, and in the NAFTA model, by crop and area

Crop/	Acreage			
Area	Baseline	MB Ban	NAFTA	MB Ban and NAFTA
	(-----------------------------Acres-----------------------------)			
Tomatoes				
Florida				
Dade	4,408	0	0	0
Palm Beach	2,798	0	0	0
West Central	11,077	12,020	12,761	11,804
Southwest	20,975	22,763	22,288	22,467
California	36,408	35,206	0	0
Alabama/Tennessee	3,448	0	0	0
South Carolina	6,923	8,823	8,595	8,677
Virginia/Maryland	6,282	6,179	6,249	6,195
Mexico				
Sinaloa	34,951	39,235	38,583	40,468
Baja	5,369	6,497	27,583	27,472
Total	132,641	130,723	116,060	117,082
Bell Peppers				
Florida				
Palm Beach	7,175	6,986	7,131	6,829
West Central	10,997	9,499	10,900	9,821
Texas	12,680	14,458	12,727	13,963
Mexico/Sinaloa	13,600	13,901	13,963	14,551
Total	44,452	44,845	44,721	45,165
Cucumbers				
Florida/Palm Beach	6,693	6,986	6,769	6,829
Mexico/Sinaloa	10,076	10,304	10,361	10,361
Total	16,769	17,290	17,130	17,190
Squash				
Florida				
Dade	8,081	7,880	7,647	7,749
Southwest	3,637	4,423	4,286	4,568
Mexico/Sinaloa	7,265	7,210	7,371	7,399
Total	18,984	19,513	19,304	19,716

Note: MB is abbreviated for Methyl Bromide.

Table 3-3. Continued

Crop/ Area	Acreage Baseline	MB Ban	NAFTA	MB Ban and NAFTA
	(------------------------------Acres------------------------------)			
Eggplant				
Florida/Palm Beach	5,327	5,132	5,247	5,075
Mexico/Sinaloa	2,734	2,862	2,897	3,000
Total	8,060	7,994	8,143	8,075
Watermelons				
Florida				
West Central	1,812	593	1,694	923
Southwest	17,338	18,340	18,002	17,899
Total	19,149	18,933	19,697	18,822
Strawberries				
Florida/West Central	4,545	4,692	4,545	4,692
California				
Southern	10,518	7,659	10,518	7,659
Northern	9,217	0	9,217	0
Total	24,280	12,351	24,280	12,351

Note: MB is abbreviated for Methyl Bromide.

Table 3-4. Baseline production and percentage changes in production crops in the methyl bromide ban effect and in the NAFTA effect, by area

Area	Production Baseline	MB Ban	NAFTA	MB Ban and NAFTA
	(Units)	(-------------------------%-------------------------)		
Florida	103,851	(6.91)	(7.61)	(7.60)
California	92,674	(31.12)	(42.43)	(72.15)
Texas	7,735	14.02	0.37	10.12
Virginia/Maryland	4,272	(1.64)	(0.52)	(1.38)
South Carolina	6,854	27.44	24.14	25.34
Alabama/Tennessee	2,138	(100.00)	(100.00)	(100.00)
United States	217,524	(16.21)	(21.93)	(34.22)
Mexico	94,509	11.01	50.74	54.78
Total	312,033	(7.97)	0.08	(7.26)

Note: MB is abbreviated for Methyl Bromide.

Table 3-5. Baseline production and percentage changes in production crops in the methyl bromide ban effect and in the NAFTA effect, by crop and area

Crop/ Area	Production			
	Baseline	MB Ban	NAFTA	MB Ban and NAFTA
	(Units)	(---------------------------%--------------------------)		
Tomatoes				
Florida	56,506	(10.86)	(10.35)	(12.16)
California	39,321	(3.30)	(100.00)	(100.00)
Alabama/Tennessee	2,138	(100.00)	(100.00)	(100.00)
South Carolina	6,854	27.44	24.14	25.34
Virginia/Maryland	4,272	(1.64)	(0.52)	(1.38)
United States	109,091	(7.11)	(41.87)	(42.77)
Mexico	73,786	13.42	64.10	68.50
Total	182,876	1.17	0.89	2.13
Bell Peppers				
Florida	18,172	(9.28)	(0.78)	(8.37)
Texas	7,735	14.02	0.37	10.12
United States	25,907	(2.33)	(0.44)	(2.85)
Mexico	10,282	2.22	2.67	6.99
Total	36,189	(1.04)	0.45	(0.06)
Cucumbers				
Florida	4,016	4.38	1.14	2.04
Mexico	5,572	2.26	2.83	2.83
Total	9,588	3.15	2.12	2.50
Squash				
Florida	4,395	4.99	1.83	5.11
Mexico	1,518	(0.76)	1.46	1.85
Total	5,913	3.51	1.73	4.27
Eggplant				
Florida	7,457	(3.65)	(1.50)	(4.73)
Mexico	3,352	4.69	5.96	9.75
Total	10,809	(1.07)	0.81	(0.24)
Watermelon				
Florida	6,475	(0.76)	2.91	(1.44)
Strawberries				
Florida	12,725	3.24	0.00	3.24
California	53,354	(51.62)	0.00	(51.62)
Total	66,079	(41.06)	0.00	(41.06)

Note: MB is abbreviated for Methyl Bromide.

Table 3-6. Baseline revenues and changes in revenues from the methyl bromide ban effect and the NAFTA effect, by crop and area

Crop/ Area	Revenue ($)			
	Baseline	MB Ban	NAFTA	MB Ban and NAFTA
Tomatoes				
Florida	448,227,870	(56,878,770)	(46,798,270)	(62,753,470)
California	286,004,000	(9,442,000)	(286,004,000)	(286,004,000)
Alabama/Tennessee	20,477,170	(20,477,170)	(20,477,170)	(20,477,170)
South Carolina	71,270,950	19,210,230	17,207,920	17,712,950
Virginia/Maryland	42,736,960	(700,600)	(222,390)	(591,470)
United States	868,716,950	(68,288,310)	(336,293,910)	(352,113,160)
Mexico	496,178,430	67,177,520	332,710,470	353,716,970
Total	1,364,895,380	(1,110,790)	(3,583,440)	1,603,810
Bell Peppers				
Florida	171,026,490	(17,069,120)	(994,830)	(16,315,310)
Texas	58,828,370	8,248,660	218,480	5,954,450
United States	229,854,860	(8,820,460)	(776,350)	(10,360,860)
Mexico	102,449,600	2,269,300	1,678,200	6,061,900
Total	332,304,460	(6,551,160)	901,850	(4,298,960)
Cucumbers				
Florida	26,579,760	(79,510)	104,430	(302,210)
Mexico	64,228,410	997,490	1,243,710	1,243,700
Total	90,808,170	917,980	1,348,140	941,490
Squash				
Florida	51,107,510	327,680	322,760	185,970
Mexico	19,105,090	(145,080)	125,260	198,630
Total	70,212,600	182,600	448,020	384,600
Eggplant				
Florida	56,568,750	(3,663,070)	(847,960)	(4,254,770)
Mexico	25,895,360	1,214,100	1,188,020	2,155,720
Total	82,464,110	(2,448,970)	340,060	(2,099,050)
Watermelon				
Florida	11,799,539	(7,874,013)	(976,981)	(5,667,189)
Strawberries				
Florida	93,912,080	17,912,420	0	17,912,420
California	466,867,600	(263,289,100)	0	(263,289,100)
Total	560,779,680	(245,376,680)	0	(245,376,680)

Note: MB is abbreviated for Methyl Bromide.

Table 3-7. Baseline revenues and changes in revenues from the methyl bromide ban effect and the NAFTA effect, by area

	Revenue ($)			
Area	Baseline	MB Ban	NAFTA	MB Ban and NAFTA
Florida	853,322,230	(70,941,450)	(64,809,740)	(76,712,610)
California	752,871,600	(272,731,100)	(286,004,000)	(549,293,100)
Texas	58,828,370	8,248,660	218,480	5,954,450
Virginia/Maryland	42,736,960	(700,600)	(222,390)	(591,470)
South Carolina	71,270,950	19,210,230	17,207,920	17,712,950
Alabama/Tennessee	20,477,170	(20,477,170)	(20,477,170)	(20,477,170)
United States	1,799,507,280	(337,391,430)	(354,086,900)	(623,406,950)
Mexico	707,856,890	71,513,330	336,945,660	363,376,920
Total	2,507,364,170	(265,878,100)	(17,141,240)	(260,030,030)

Note: MB is abbreviated for Methyl Bromide.

Table 3-8. Baseline average prices and percentage changes in prices from the methyl bromide ban effect and the NAFTA effect, by crop

	Price			
Crops	Baseline	MB Ban	NAFTA	MB Ban and NAFTA
	($/unit)	(---------------------------	%-------------------------	)
Tomatoes	8.69	1.46	(0.52)	0.82
Bell Peppers	6.14	1.35	(0.24)	0.90
Cucumbers	7.71	(0.40)	(0.65)	(0.36)
Squash	6.96	(0.18)	(0.50)	(0.41)
Eggplant	4.81	1.26	(0.36)	0.87
Watermelon	1.15	5.13	(1.42)	5.39
Strawberries	11.77	12.78	0.00	12.78

Note: MB is abbreviated for Methyl Bromide.

Table 3-9. Baseline demand and percentage changes in demand from the methyl bromide ban effect and the NAFTA effect, by crop and market

Crop	Market	Baseline	MB Ban	NAFTA	MB Ban and NAFTA
		(Units)	(--------------------%--------------------)		
Tomatoes					
	Atlanta	41,080	(1.05)	1.26	0.39
	Los Angeles	33,871	(0.82)	0.86	0.18
	Chicago	38,744	(1.44)	0.96	(0.24)
	New York	66,763	(1.33)	0.51	(0.75)
Bell Peppers					
	Atlanta	9,955	(3.37)	0.06	(2.60)
	Los Angeles	5,529	(1.15)	1.56	0.84
	Chicago	11,399	(2.19)	0.79	(1.32)
	New York	9,305	(5.91)	0.21	(5.26)
Cucumbers					
	Atlanta	2,077	1.07	2.81	(0.01)
	Los Angeles	1,988	1.60	2.00	2.00
	Chicago	2,943	0.72	1.97	(0.07)
	New York	2,580	0.66	1.84	(0.11)
Squash					
	Atlanta	1,808	0.58	1.10	0.81
	Los Angeles	1,690	0.42	2.19	1.98
	Chicago	1,686	0.61	1.15	0.84
	New York	728	1.92	3.58	2.60
Eggplant					
	Atlanta	1,673	(11.55)	0.17	(11.15)
	Los Angeles	2,991	(0.13)	2.34	1.90
	Chicago	3,983	(2.68)	0.16	(2.12)
	New York	2,162	(7.89)	0.41	(7.74)
Watermelon					
	Atlanta	468	(59.90)	16.55	(62.93)
	Los Angeles	1,348	(6.28)	1.73	(6.60)
	Chicago	1,484	(11.64)	3.22	(12.23)
	New York	3,174	(4.55)	1.26	(4.78)
Strawberries					
	Atlanta	11,088	(66.57)	0.00	(66.57)
	Los Angeles	16,215	(43.99)	0.00	(43.99)
	Chicago	17,554	(49.56)	0.00	(49.56)
	New York	20,649	(47.09)	0.00	(47.09)

Note: MB is abbreviated for Methyl Bromide.

CHAPTER 4
SUMMARY AND CONCLUSIONS

Summary

The purpose of an economic impact analysis is to help planners, analysts, and interested individuals estimate the total economic effect of a change in a particular sector or industry on a region's output, income earnings, and employment. Our study used a spatial equilibrium model to investigate the economic impact of NAFTA and the ban on methyl bromide for fruits and vegetables produced in the United States. Our spatial equilibrium model satisfies the utility-maximization condition by using the elasticities from the inverse demand system (we investigated the method to estimate the inverse demand system in Chapter 2). The results from Chapter 2 showed that by using the mean of the budget share to develop the inverse demand model, the estimation of the elasticities is the same across all functional forms of the inverse demand system. We estimated the inverse demand system by using Barten's method of estimation with homogeneity and symmetry constraints imposed. Overall, Chapter 2 provided the method to estimate the elasticities for selected fruits and vegetables in the U.S. market by using a model that can obviate the need to choose among the popular functional forms.

Based on the results of the estimated coefficients, the scale effects of all commodities in every market are statistically significant at the 5% probability level and they have the expected sign. In terms of own substitution, they all have the expected sign, according to theory, and they are statistically significant at the 5% probability level for all commodities in the Atlanta, Los Angeles, and New York markets. Strawberry is

the only crop that is statistically significant at the 5% probability level in the Chicago market. In every market, tomato has the highest absolute value of own uncompensated quantity elasticity, while strawberry has the lowest absolute value. Own substitution elasticities for tomato and bell pepper are higher in the Atlanta and Los Angeles markets than they are in the Chicago and New York markets.

In Chapter 3, we investigated the economic impacts of NAFTA and the phaseout of methyl bromide on the U.S. fruit and vegetable industry by applying the demand elasticities from Chapter 2 into the VanSickle et al. model. The VanSickle et al. model is a spatial equilibrium model that satisfies the profit-maximizing condition, utility-maximizing condition, and market-clearing condition. The fruit and vegetable crops that have been identified as having the most potential for being impacted by a ban on methyl bromide are tomatoes, bell peppers, eggplant, squash, cucumbers, strawberries, and watermelons. Mexico is expected to become the major supplier of these crops because of NAFTA and the Montreal Protocol.

The results from Chapter 3 show that total production of these crops in the United States is expected to decrease by 34.22% under the third scenario (a combination of impacts from NAFTA and a ban on methyl bromide). For example, California's production could decrease by 72.15% with tomato production ceasing under the second scenario and strawberry production ceasing under the first scenario. In addition, under the third scenario, total production in Florida is expected to decrease by 7.6%, while total production in Mexico is expected to increase by 54.78%.

Knowing the impact these policies will have on Florida and California growers, policy makers should develop programs that will speed the search for alternatives to

methyl bromide. In the interim, policy makers should consider programs that can help growers survive over the short run from these impacts.

Suggestions for Further Research and Limitation of the Study

This study provides useful information for discussion about competition in the market for tomatoes, bell peppers, cucumbers, squash, eggplant, watermelons, and strawberries. Other commodities could also benefit from a similar study. Other areas of research would likely enhance the investigation of competition between Florida and Mexico and of production results from both areas on the vegetable market.

The primary limitation of the study is the assumption regarding finding alternatives to using methyl bromide as a pre-plant fumigant. The development of economically viable alternative fumigants or alternative non-fumigant production systems would alter the empirical results of this study. Another limitation of the study is that alternative crops were not extensively analyzed. The assumption was made that current market conditions limit the potential for expanding the production of these crops. The process of identifying and developing successful production systems and markets could be difficult. In addition, the methodology used to estimate the economic impact of the methyl bromide ban is deterministic based on average yield and cost of production data. In reality, there is significant year-to-year variation in harvested production per acre in fresh fruit and vegetable production. Variation in crop yields is a result of both weather and economic factors. The uncertainty faced by fresh fruit and vegetable producers is ignored in this study.

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I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

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